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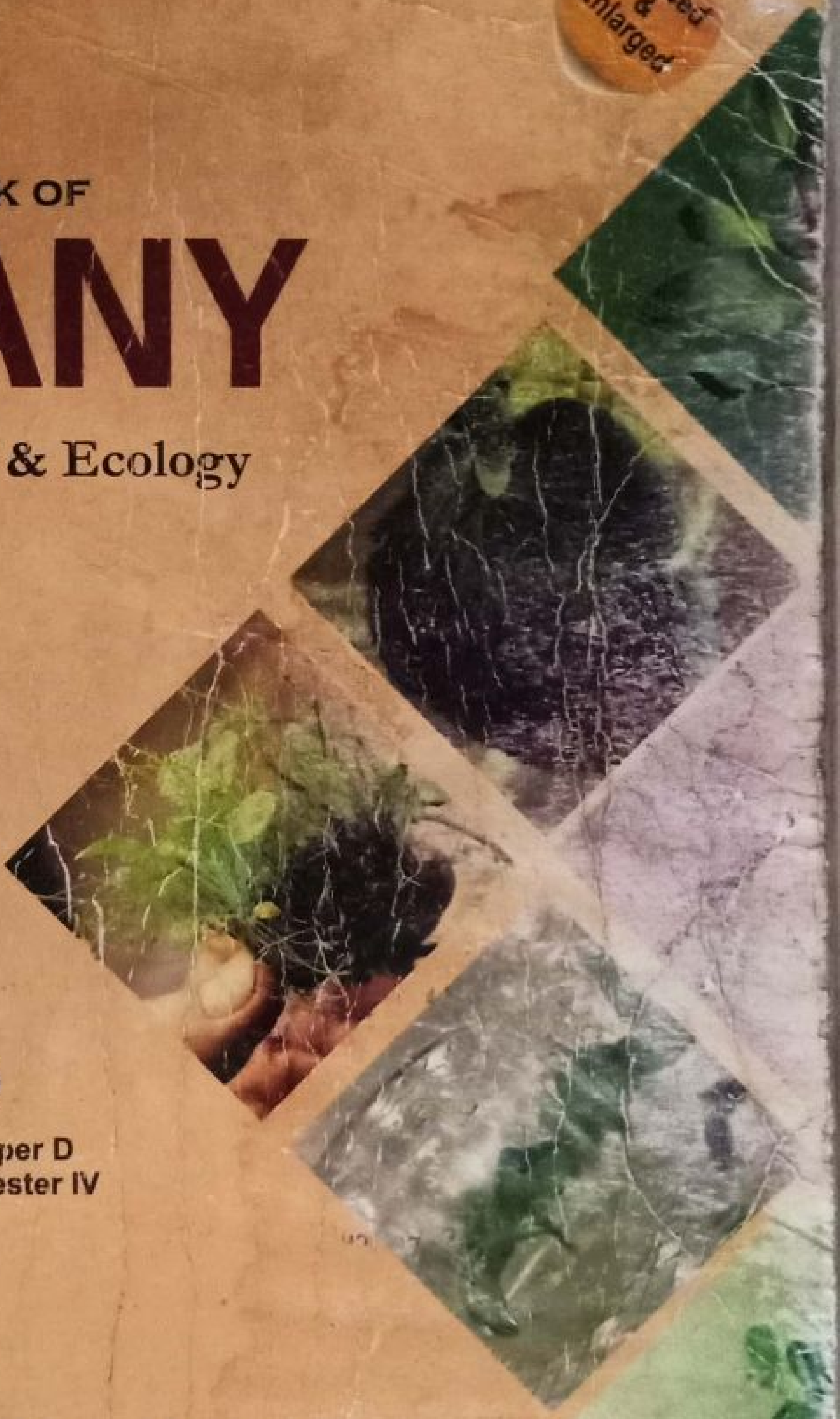
TEXT BOOK OF

BOTANY

Plant Physiology & Ecology



Paper D

B.Sc. (Two Years): Paper D
B.S. (Four Years): Semester IV

Prof. Iftikhar Ahmad Khan
Prof. Riaz-ul-Haq Ramay

According to Syllabus of All the Universities of Pakistan

DOCTOR
MASTER SUCCESS B.Sc./B.S. Series

Text Book of Botany D

PLANT PHYSIOLOGY & ECOLOGY Paper D

PAPER D FOR B.SC
For B.S. 4th Semester 2nd year

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(first four semesters) of B.S. is almost similar to B.Sc syllabus though some differences are there. That is why we have revised all the books of botany. Some topics of B.S. syllabus have been added. Now Master Success Botany books completely fulfill the need of syllabi of B.S and B.Sc both. Attention has been paid to clarity of diagrams and text. Some topics are completely revised.

We hope that this new edition will also occupy your attention. We do hope that this effort will bear fruit. We hope that this effort will be well taken by teachers and student. We encourage criticism. Please don hesitate to write us, email us or ring us if you feel any difficulty in this book.

August, 2010

Prof. Iftikhar Ahmad Khan
Prof. Riaz-ul-Haq Ramay
Phone: 0300-6366320
E-mail: ramay11@hotmail.com

PREFACE FOR NEW REVISED EDITION (Third generation botany)

Thanks God our Second generation botany served the need of so many students throughout Pakistan for so many years. I am much obliged to all the Professors and other teaching faculties of all the colleges and Universities for their kind cooperation and suggestions.

Science is a dynamic tool of thoughts which needs to be sharpened day by day. We must keep abreast with these changing thoughts in modern sciences. That is why we were approached by so many worthy teachers to bring new changes in this text book. Thanks God our third generation botany is now in your hand. You will feel marvelous changes in this new edition. The size of book is enlarged as per demand of the teachers and students. Though students have to bear a little much financial burden but it will give them new manuscript having well illustrated diagrams. Most of the topics are revised in the book. Well illustrated diagrams are added. Easy style of the book is well maintained.

We live in hope that this third generation botany new edition will also occupy your attention. We do hope that this effort will bear fruit. We hope that this effort will be well taken by teachers and student. We encourage criticism. Please do not hesitate to write us, email us or ring us if you feel any difficulty or want to give any suggestion about this book.

June, 2016

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216-27 → Int.
228-233 → Lit + temp.
254-259 → water + wind

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SYLLABUS of B.Sc (Two years)
(Approved by Higher Education commission HEC) for all the Universities of Pakistan)

A: Plant Physiology

1. Types and properties of solutions, Electrolytes and non-electrolytes, SI units of expressing concentration of solutions, Acids, bases, and salts, pH, Definition of buffers and their role in biological systems, Colloidal system, Their nature, properties and biological significance
2. Diffusion, imbibitions, osmotic and osmotic components, Water relations, (water potential, pressure potential, matric potential, Absorption and translocation of water, Transpiration, factor affecting transpiration, Stomatal structure and function (Stomatal physiology)
3. Mineral Nutrition: Soil as a source of minerals, Passive and active transport, Essential mineral elements their role and deficiency symptoms, emphasis on Ca, N, K and P.
4. Enzymes: Definition, nature, classification and properties
5. Photosynthesis: The process of photosynthesis, Absorption and action spectra, Mechanism: Light reactions (electron transport chain and photophosphorylation) and dark reaction (Calvin cycle), , Factors affecting photosynthesis: Concept of limiting factors, Product of photosynthesis,
6. Respiration: Definition and mechanism, Glycolysis, Krebs cycle, Electron transport chain, Oxidative phosphorylation, anaerobic respiration, Respiratory substrates and respiratory quotients.
7. Nitrogen Metabolism: Biological nitrogen fixation
8. Growth: Definition, Role of auxins, gibberellins, cytokinins, abscisic acid and ethylene in controlling growth, Introduction to plant tissue culture
9. Photoperiodism: Definition, historical background, Short day, long day and day neutral plants, Role of phytochromes and hormones in photoperiodism
10. Seed dormancy: Definition and causes of seed dormancy, Methods of breaking seed dormancy
11. Vernalization: Vernalization: Annual and biennial forms, Hormonal concept and phasic development theory
12. Plant movements: Tropic movements: phototropism, gravitropism and their mechanism, Nastic movements

B: Plant Ecology

1. Concepts of Ecology
2. History of Ecology
3. Ecophysiology:
   (a) Light and temperature responses: Quality of light, Variation in light (temperature), Ecophyiological responses
   (b) Edaphology: Brief introduction of soil forming process, Texture, structure and

water, Chemical properties of soil, Biological components: Soil organism, Organic matter

(c) Water: Precipitation, kinds and affectivity, Distribution of vegetation in relation to moisture

(d) Wind: Ecological importance of wind

4. Population Ecology: A brief introduction: History and background, Seed dispersal, Seed bank, demography, reproductive strategy
5. Community Ecology: Concepts of plant community, attributes, Sampling methods, Succession – history, concept, development and modern theories of succession, Brief concept of productivity, Local vegetation
6. Ecosystem: Definition and background, Ecological energetic, Biogeochemical cycle (Hydrologic and nitrogen cycle)
7. Applied Ecology: Aridity, Biodiversity, Conservation, Water logging and salinity, Pollution, Erosion, Desertification, management

SYLLABUS of B.S. (Four years)

4th SEMESTER

Title of the course: BOT-402 Plant Physiology and Ecology
Credit hours: 4(3+1)
Prerequisites: Bot-301, 302, 401
Course outline:

a) Plant Physiology

1. Water relations (water potential, osmotic potential, pressure potential, matric potential). Absorption and translocation of water. Stomatal regulation.
2. Mineral nutrition: Soil as a source of minerals. Passive and active transport of nutrients. Essential mineral elements, role and deficiency symptoms of macronutrients.
3. Photosynthesis: Introduction, Oxygenic and non-oxygenic photosynthesis Mechanism: light reactions (electron transport and photophosphorylation) and dark reactions (Calvin cycle). Differences between C_3 and C_4 plants. Factors affecting this process, Products of photosynthesis.
4. Respiration: Definition and respiratory substrates. chanism-Glycolysis, Krebs cycle. Electron transport and oxidative phosphorylation.
5. Anaerobic respiration. Energy balance in aerobic and anaerobic respiration, Respiratory quotients.
6. Growth: Definition; role of auxins, gibberellins,cytokinins, abscisic acid and ethylene in controlling growth. Introduction to plant tissue culture.

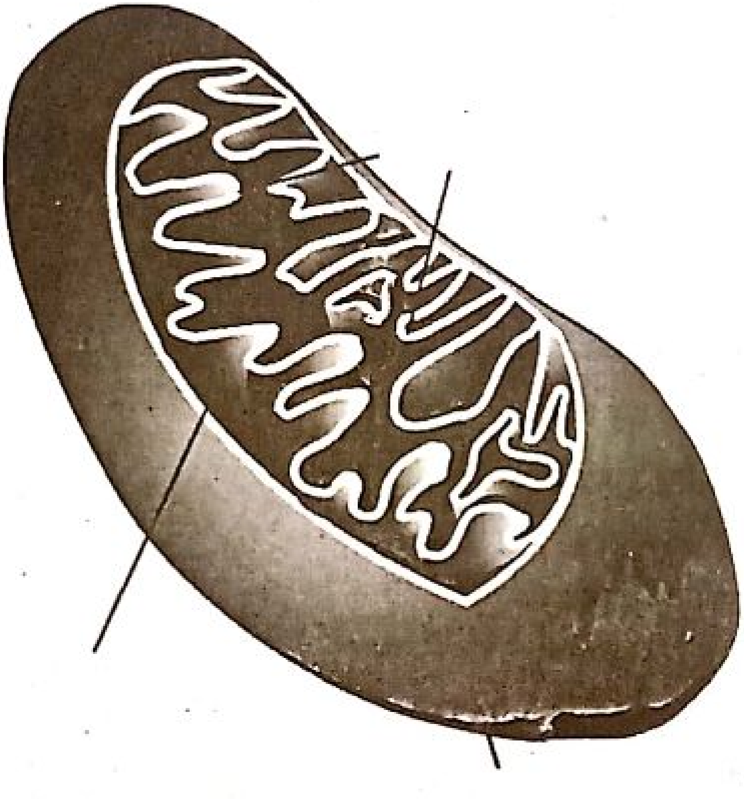
7. **Photoperiodism:** Definition, historical background, Classification of plants based on photoperiodic response, Role of phytochromes, and hormones and metabolites in photoperiodism,
8. **Dormancy:** Definition and causes of seed and bud dormancy; methods of breaking seed dormancy. Physiological processes during seed germination.
9. **Plant Movements:** Classification. Tropic movements- phototropism, gravitropism and their mechanisms. Nastic movements.

b) Ecology

1. Introduction; aims and applications of ecology.
2. Soil: Physical and Chemical properties of soil (soil formation, texture. pH, EC, organism and organic matter etc) and their relationships to plants.
3. Light and Temperature. Quality of light, diurnal and seasonal variations. Ecophysiological responses.
4. Water: Field capacity and soil water holding capacity. Characteristics of xerophytes and hydrophytes. Effect of precipitation on distribution of plants.
5. Wind: Wind as an ecological factor and its importance.
6. Population Ecology: Introduction. A brief description of seed dispersal, seed bank, demography, density effects and reproductive strategy.
7. Community Ecology
    - i. Ecological characteristics of plant community
    - ii. Methods of sampling vegetation (Quadrat and line intercept)
    - iii. Succession.
    - ✓ iv. Major vegetation types of the local area. Pak. — (292)
8. Ecosystem Ecology
    - i. Definition, types and components of ecosystem.
    - ii. Food chain and Food web.
    - iii. Biogeochemical cycles, definition, types with emphasis on Nitrogen & Hydrological cycles.
9. Applied Ecology
    - **i.** Causes, effects and control of water logging and salinity with respect to Pakistan
    - **ii.** Soil erosion: types, causes and effects (wind and water)
    - **iii.** Brief concept of pollution types and effects (air, sediments and water pollution)
    - **iv.** Brief introduction to biodiversity and conservation with emphasis on Pakistan.

Part A

PLANT PHYSIOLOGY



Chapter 1

SOLUTIONS, ACID, BASE AND COLLOIDALS

Syllabus

1. Types and properties of solutions
2. Electrolytes and non-electrolytes
3. SI units of expressing concentration of solutions
4. Acids, bases, and salts
5. pH
6. Definition of buffers and their role in biological systems
7. Colloidal system, Their nature, properties and biological significance

SOLUTIONS

A homogeneous mixture of two or more substances is called solution. The dissolved substance is called **solutes**. The substance which dissolves a solute is called **solvent**. The solutions in which water acts as solvent are called aqueous solutions. Its example is solution of water and salt.

Types of solutions

There are following types of solutions

1. **Dilute Solution:** A solution with small amount of solutes is called dilute solution.
2. **Concentrated solutions:** A solution with a large amount of solutes is called concentrated solution.
3. **Saturated Solution:** A solution in which more solutes cannot be dissolved is called saturated solution. If the solute is added continuously a stage comes when the solute starts settling down. This stage is saturated solution.
4. **Supersaturated Solution:** A saturated solution that can dissolve more solute when the temperature is increased is called supersaturated solution. Increases in temperature increases solubility of a solid in liquid. Thus the excess solute dissolves on heating. It forms a supersaturated solution. If more solute is added to a supersaturated solution the excess amount of solute will crystallize. Thus a saturated solution left.

Properties of solutions

There are following properties of solutions.

1. The particles of solutes are present in the form of molecules or ions.
2. There is a uniform distribution of solutes particles in the solvent.
3. The solutes can pass through a filter.
4. The solution shows process of osmosis and diffusion.
5. Solution can diffuse through a semi- permeable membrane.
6. The particles are not visible to naked eye.
7. The solutes do not scatter light rays.

ELECTROLYTES AND NON-ELECTROLYTES

Electrolytes

The substances that conduct electric current in aqueous solution are called electrolytes. Electric current decompose an electrolyte into its ions. **The process of decomposition of electrolytes into its ions is called electrolysis.** For example, electric current is passed through an aqueous solution of sodium chloride. It is ionized into Na^+ and Cl^-. Na^+ is deposited at cathode and chlorine (Cl_2) gas at the anode. Acids, bases and salts are electrolytes.

Non-Electrolytes

The substances which do not conduct electric current are called non - electrolytes. Non – electrolytes do not ionized. Sugar, lipids and alcohols are non-electrolytes.

SI units of expressing concentration of solutions

The concentration of a solution is expressed by following methods:

1. Percentage

The volume or weight (concentration) of some solute is expressed in the percentage. For example 10 gm of sodium chloride is added in 90 gm of water. It is called 10% solution.

2. Molarity

The number of moles of a solute per liter of a solution is called molarity. One mole of any substance is equal to its molecular weight. A gram molecular weight of a substance is dissolved in water to make exactly one liter of solution at 20 °C. It called a molar solution (M). For example, the molecular weight of sucrose is 342.3. A molar (I M) solution of sucrose contains 342.3 grams of sucrose. It is dissolved in one liter of the solution. It becomes one molar solution.

The solutions expressed in terms of molarity can be diluted arithmetically.

3. Molality

The number of moles of a substance dissolved in 1000 cm^3 of solution is called molality. Gram molecular weight of a substance is dissolved in 1000 cc of water. It produces molal solution.

ACIDS, BASES & SALTS

Acid

An acid is a substance that releases hydrogen ions (H^-) when dissolved in water. A hydrogen atom without its electron is only a proton. Thus an acid is a proton donor:

$$HCl \longrightarrow H^+ + Cl^-$$

One molecule of hydrogen chloride dissolves in water to produce hydrochloric acid. It dissociates into one hydrogen ion and one chloride ion.

Base (or alkali)

A substance that releases hydroxyl ions (OH^-) when dissolved in water is called base. One molecule of sodium hydroxide dissolves in water. It produces one sodium ion and one hydroxyl ion. When a base dissolves in water, it removes free protons (H^+) from the water. Therefore, it is a proton acceptor.

$$NaOH \longrightarrow Na^+ + OH^-$$

Salts

The acids and bases can neutralize one another to form a salt and water. The salts are found in all cells. They exist in their ionized forms. Examples of salt are sodium chloride etc.

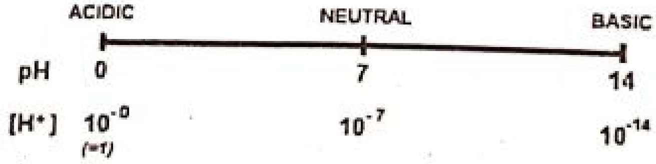
pH: MEASURING ACIDITY AND ALKALINITY

The negative log (antilog) of hydrogen ion concentration is called pH.

$$pH = -\log[H+] \text{ Concentration}$$

Hydrogen and hydroxyl ions affect the chemical reactions in the cells. Therefore, concentrations of these ions in body fluids are important. The higher the concentration of hydrogen ions (H^+), the more acidic is the solution. The higher the concentration of hydroxyl (OH^-) ions, more basic is (alkaline) the solution. A neutral solution has equal number of hydrogen ion and hydroxyl ions. The **pH scale** measures acidity and alkalinity. It runs from 0 to 14.

- Acidic solutions have a pH less than 7.
- The basic (alkaline) solutions have a pH above 7.
- A pH of 7 is neutral.



Each whole number on the pH scale represents a tenfold change (logarithmic) in acidity. Therefore, a solution with a pH of 3 is 10 times more acidic than a solution with a pH of 4. A pH of 9 is 10 times more basic than a pH of 8.

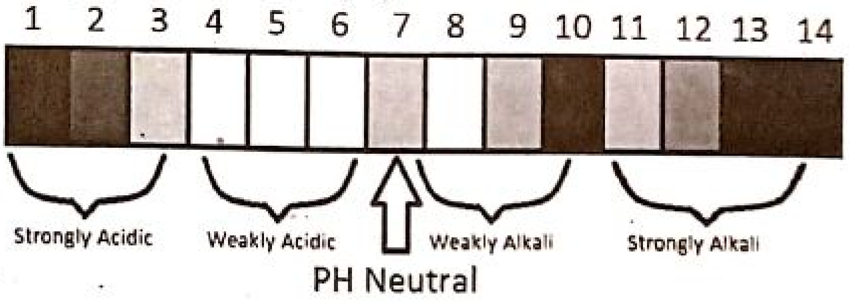
For example we have very low H^+ concentration, lets say about 0.0000001M. Then the pH is:

$$pH = -\log[.0000001]$$

It is the same as $-\log[1 \text{ X } 10^{-7}]$

Thus $\log[1 \times 10^{-7}] = -7$

$-(-7) = 7$



BUFFERS

The substance which resists change in pH is called buffer. Stable internal environment is maintained in animals. It requires a relatively constant pH of the body fluids. A strong acid or base can destroy cell stability. Similarly, opposite charges attract each other and form the ionic bond.

Change in pH may be destructive. The fluid systems of most animals contain chemicals. These substances help to regulate the acid base balance. These substances are called **buffers. Buffers** are mixture of weak acids and their salts of strong bases. They may also be mixture of weak bases and their salts of strong acids. Buffers resist changes in pH. They accept H^+ ions present in excess. They donate H^+ ions when their amount is reduced.

Fluids are present within the cell and surrounding the cells. All multicellular organisms have a characteristic and nearly constant pH. This pH is maintained in a number of ways. Buffer systems are the most important for maintaining pH. Two important biological buffer systems are dihydrogen phosphate system and carbonic acid system. Organic molecules like amino acids and proteins also act as buffers.

1. Carbonic acid buffer

The carbonic acid bicarbonate ion system is important in buffering the blood of many vertebrates:

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Carbonic acid dissociates to form hydrogen ion and bicarbonate ion. In this example, if H^+ ions are added to the system, they combine with HCO_3^- to form H_2CO_3 (the reaction goes to the left). This reaction removes H^+ ions. So it does not allow changing the pH. If excess OH^- ions are added, they react with the H^- ions to form water. So more H_2CO_3 ionize and replace the H^+ ions. Thus the reaction goes to the right. Again, pH stability is maintained.

2. Phosphate buffer

The phosphate buffer system operates in the internal fluid of all cells. This buffer system consists of two ions. These are

- Dihydrogen phosphate ions ($H_2PO_4^-$) as hydrogen-ion donor (acid)
- Hydrogen phosphate ions (HPO_4^{2-}) as hydrogen-ion acceptor (base).

These two ions are in equilibrium with each other. This equilibrium is indicated by following chemical equation.

$$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$$

Additional hydrogen ions may enter the cellular fluid. These ions are consumed in the reaction with HPO_4^{2-}. Thus the equilibrium shifts to the left. Similarly, additional hydroxide ions may enter the cellular fluid. These ions react with $H_2PO_4^-$. It produces HPO_4^{2-}. Thus the equilibrium shifts to the right. The equilibrium-constant expression for this equilibrium is:

$$K_a = \frac{[H^+][HPO_4^{2-}]}{[H_2PO_4^-]}$$

The value of K_a for this equilibrium is 6.23×10^{-8} at 25°C. There is a relationship between the hydrogen-ion concentration and the concentrations of the acid and base. This relationship can be derived from this equation.

$$[H^+] = K_a \frac{[H_2PO_4^-]}{[HPO_4^{2-}]}$$

In some cases, concentrations of $H_2PO_4^-$ and HPO_4^{2-} are the same. Now the value of molar concentration of hydrogen ions is equal to the value of equilibrium constant. At that time pH is equal to the pK_a (–log K_a), namely 7.21. Buffer solutions are most effective at maintaining a pH near the value of the pK_a.

3. Protein Amino acids Buffers

Protein buffer systems depend upon proteins. Some proteins act as buffers. These proteins consume small amounts of acid or base. Proteins containing amino acid histidine are particularly important for buffering of fluids.

Role of buffers in biological system

Buffers play following role in the biological system

1. **Protection of enzymes:** Enzymes function within narrow pH range. A slight change in pH inhibits enzyme activity. For example, a slight change in pH affect phosphorylase enzyme. This enzyme converts starch in to glucose. The glucose increases the osmotic pressure of guard cells. Thus water enters into the guard cells and stomata are opened. Phosphorylase is sensitive to pH changes. Thus change in pH can affect the opening and closing of stomata. Similarly Enzymes of glycolysis and Krebs cycle are sensitive to change in pH. Thus buffer keeps pH stable in this system.
2. **Protection from ionization of sensitive cell compounds:** Cells are composed of different types of proteins and nucleic acids. Change in pH causes ionization of these compounds. Thus these compounds may denature. Buffer system maintains the pH in cell. Thus these compounds remain save.
3. **pH of blood:** The pH of blood remains within the range of 7.35 and 7.45. An increase in acidity causes **acidosis**. The decrease in acidity causes **alkalosis**. Both these conditions are dangerous for the body. Thus buffer keeps the pH of blood within normal range. The carbonate buffer is the principal buffer in blood. It is composed of

carbonic acid and bicarbonate ion (H_2CO_3 and HCO_3^-). Carbonic acid neutralizes OH^-. The bicarbonate neutralizes H^+ proton.

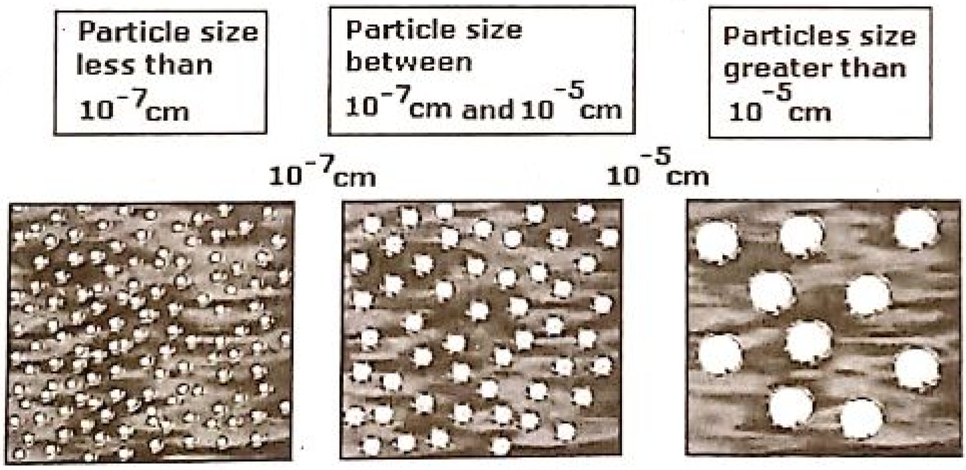
4. **Use of buffer in culture medium:** Bacteria are grown in culture medium in microbiological labs. Bacteria produce acids during reproduction. It changes the pH of the medium. The buffers are added to these media. It stabilizes the pH.

COLLOIDAL SYSTEM

A heterogeneous mixture in which solute particles are larger than molecules or ions but cannot be seen by naked eye is called colloidal solution. A system which shows properties of colloidal solution is called colloidal system. Its example is clay in water or starch in water.

The solvent is called the **dispersion medium** in a colloidal solution. The solid solute particles are called **dispersed medium** in colloidal solution. The dispersion medium may be a liquid, gas or solid.

- Smoke is composed of a solid dispersed in gas.
- Milk is a liquid dispersed in liquid
- Pumice stone is gas dispersed in s solids


Particle size less than 10^{-7}cm
Particle size between 10^{-7}cm and 10^{-5}cm
Particles size greater than 10^{-5} cm
10^{-7}cm
10^{-5} cm

True solution Colloidal solution Suspensions

Classification of Colloidal System

There are two forms of colloidal systems:

1. **Sol:** A system composed of non-viscous colloidal solution is called sol. For example milk.
2. **Gel:** A system composed of viscous colloidal solution is called gel. For example butter.

The colloidal systems can be classified into two general classes on the basis of their affinity for liquids:

a) **Lyophilic Systems:** The system in which dispersed phase and liquid dispersion medium attract each other is called lyophlic systems.

b) **Lyophobic Systems:** The systems in which the dispersed phase and liquid dispersion phase repel each other is called lyophobic systems.

Hydrophilic and Hydrophobic colloids

The colloidal systems can be classified into two other classes on the basis of attraction or repletion with water:

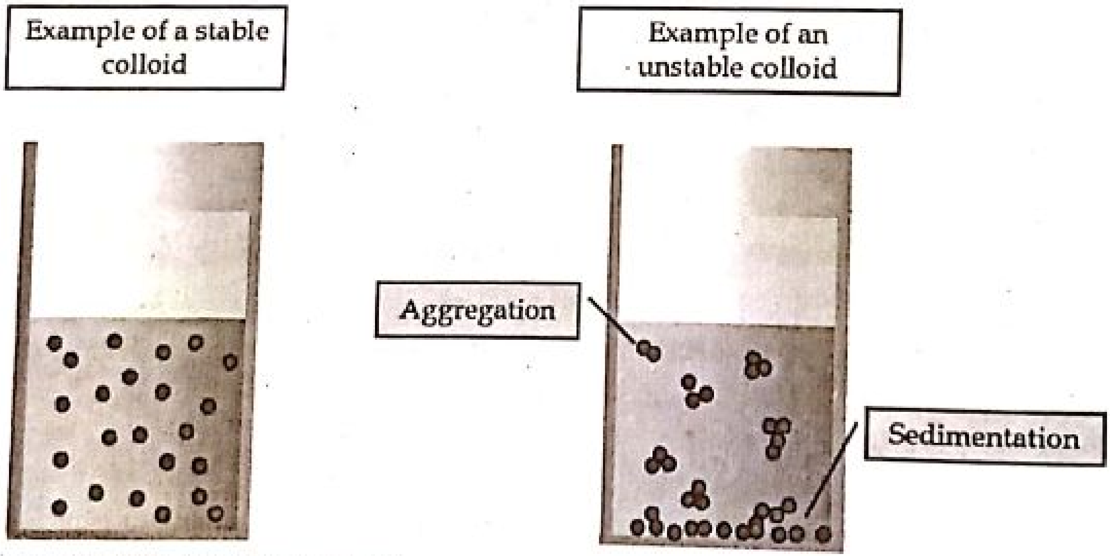
Hydrophilic Colloids or hydrocolloid

A hydrophilic colloid, or hydrocolloid, is defined as a colloid system in which the colloid particles are hydrophilic polymers dispersed in water. Hydrocolloids can be either reversible or irreversible (single-state). For example, agar is a reversible hydrocolloid of seaweed extract. It can exist in a gel or liquid state. It can alternate between these states with either heating or cooling.

Many hydrocolloids are derived from natural sources. For example, gelatin is produced by hydrolysis of proteins from cows and fish. Similarly, pectin is extracted from citrus peel and apple pomace.

Hydrophobic Colloids or emulsion

A hydrophobic colloid, or emulsion, is defined as a colloid system where the particles are hydrophobic polymers. In this case, colloid does not interact with the aqueous solvent. Therefore, hydrophobic colloids are unstable. Thus they generally do not form spontaneously. Energy input, through shaking, stirring, or homogenizing, is needed to form the emulsion. After some time an emulsion tends to separate. Separation puts it in a more stable state. The examples of hydrophobic systems are gold sol and rubber dispersed in water.



Properties of Colloidal systems

The colloidal system shows following properties

1. **Adsorption: The tendency of molecules and ions to adhere to the surface of certain solids or liquids is called adsorption.** Colloidal particles show a high tendency of adsorption. Thus, colloidal systems provide a large surface area for adsorption of molecules and ions.

2. **Brownian Movements:** Robert Brown in 1927 observed that colloidal particles show random dancing movements. These movements were named Brownian movements.
3. **Tyndall Effect:** The colloidal particles scatter light. This is called Tyndall effect. The path of light appears as a cone. It is known as **Tyndall cone**. This property helps to detect the presence of colloidal particles.
4. **Precipitation:** The additions of an electrolyte remove the electrical double layer present around the colloidal particles. As a result the dispersed particles of a colloidal suspension will aggregate and precipitate.
5. **Electrical Properties:** All colloidal particles carry same electric charge. This charge may be positive or negative. There is a adsorption of free ions in the dispersion medium. It produces an electrical double layer around the colloidal particles. The electric charges on the colloidal particles stabilize the colloidal systems.
6. **Filtration:** The colloidal particles cannot pass through a parchment membrane. This property of colloidal dispersions is used to separate them from true solution by a process called **dialysis**.
7. **Phase Reversal:** The sol and gel form of colloidal system can be interchanged due to change in certain conditions. Certain lyophilic sols form gels under certain conditions. For example, aqueous agar sols are cooled. It forms a jelly-like gel. The conversion of a sol to a gel is called **gelation**. If a gel of gelatin or agar is heated, it will convert back to a **sol**. This process is known as **solation**. The property of colloidal dispersions is called phase reversal.

Biological significance of colloidal systems

1. **Protoplasm a Colloidal system:** Protoplasm is living, viscous (semi-fluid, jelly-like) substance. It is surrounded by cell wall. It is present in all prokaryotic and eukaryotic cells. Protoplasm is colloidal in nature. The small molecules and ions are true solute particles. But larger particles remain suspended in water and form colloidal suspension.
2. **Buffering by Colloidal system:** Protoplasm shows buffering property. It is due to colloidal nature of protoplasm. Different regions of protoplasm have different pH values. Different chemical and physical activities are going on in the protoplasm. Thus pH is continuously keeps on changing in protoplasm. Colloidal system helps protoplasm to main pH in a narrow range.
3. **Cyclosis and amboeid movements:** The cyclosis occurs due to phase reversal of colloidal property. The cyclosis usually occurs in sol phase. Amoeboid movements in amoeba occur due to colloidal properties.
4. **Fruits:** Fruits store a large amount of proteins and starch. They also exhibit colloidal properties. These properties help in the storage of food in fruits.
5. **Blood:** The plasma protein forms a colloidal system in blood. This system maintains the pH and osmotic concentration of blood.
6. **Milk:** Milk is a perfect colloidal system. It contains all essential nutrients for young.

Difference between True Solution and Colloidal Solution

True Solution	Colloidal Solution
1. A homogeneous mixture of two or more substances is called solution.	1. A heterogeneous mixture in which solute particles are larger than molecules or ions but cannot be seen by naked eye is called colloidal solution.
2. Solution appears as clear and transparent.	2. It is cloudy in appearance.
3. The sizes particles of solute in solution are 10^{-7} to 10^{-8} cm.	3. The sizes particles of solute in colloidal solution are 10 to 1000 Angstrom.
4. Light pass through particles. They do not reflect light.	4. Colloidal particles disperse light.
5. They do not show Tyndall effect.	5. They show Tyndall effect.
6. Particles are not visible even under ultra-microscope.	6. Particles are visible under ultra-microscope.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Solution	A homogeneous mixture of two or more substances is called solution.
Solute	The dissolved substance is called solutes.
Solvent	The substance which dissolves a solute is called solvent.
Saturated solution	A solution in which more solutes cannot be dissolved is called saturated solution.
Supersaturated Solution	A saturated solution that can dissolve more solute when the temperature is increased is called supersaturated solution.
Electrolytes	The substances that conduct electric current in aqueous solution are called electrolytes.
Electrolysis	The process of decomposition of electrolytes into its ions is called electrolysis.
Molartiy	The number of moles of a solute per liter of a solution is called molarity.
Molarity	The number of moles of a substance dissolved in in 1000 cm^3 of solution is called molality.
Acid	An acid is a substance that releases hydrogen ions (H^-) when dissolved in water.
Base	A substance that releases hydroxyl ions (OH^-) when dissolved in water is called base.
pH	The negative log (antilog) of hydrogen ion concentration is

	called pH.
Ganglia	The substance which resists change in pH is called buffer.
Colloidal solution	A heterogeneous mixture in which solute particles are larger than molecules or ions but cannot be seen by naked eye is called colloidal solution.
Colloidal system	A system which shows propterties of colloidal solution is called colloidal system.
Dispersion and dispersed medium	The solvent is called the dispersion medium in a colloidal solution. The solid solute particles are called dispersed medium in colloidal solution.
Sol	A system composed of non-viscous colloidal solution is called sol. For example milk.
Gel	A system composed of viscous colloidal solution is called gel. For example butter.
Lyophilic Systems	The system in which dispersed phase and liquid dispersion medium attract each other is called lyophlic systems.
Lyophobic Systems	The systems in which the dispersed phase and liquid dispersion phase repel each other is called lyophobic systems
Adsorption	The tendency of molecules and ions to adhere to the surface of certain solids or liquids is called adsorption.

MODEL SUBJECTIVE QUESTIONS

1. **What are solutions? Gives its types of properties.**
2. **What are electrolytes and non-electrolytes?**
3. **Give different methods to measure the concentration of solutions.**
4. **What are acid base and salts?**
5. **What is pH? How it can be controlled by a buffer.**
6. **What are buffers? Give their role in biological system.**
7. **What are colloids and colloidal system? Give their properties.**

SHORT QUESTIONS

1. **What are solutions, solute and solvents?**

Ans: **A homogeneous mixture of two or more substances is called solution.** The dissolved substance is called **solutes**. The substance which dissolves a solute is called **solvent.**

2. **Differentiate between saturate and supersaturated solutions.**

Ans: A solution in which more solutes cannot be dissolved is called saturated solution. A saturated solution that can dissolve more solute when the temperature is increased is called supersaturated solution.

3. **Give two properties of solutions.**

Ans: The particles of solutes are present in the form of molecules or ions. There is a uniform distribution of solutes particles in the solvent.

4. **What are electrolytes and electrolysis?**

Ans: The substances that conduct electric current in aqueous solution are called electrolytes. The process of decomposition of electrolytes into its ions is called electrolysis.

5. **What are molarity and molar solution?**

Ans: **The number of moles of a solute per liter of a solution is called molarity.** One mole of any substance is equal to its molecular weight. A gram molecular weight of a substance is dissolved in water to make exactly one liter of solution at 20 °C. It called a molar solution (M).

6. **What is meant by molality?**

Ans: **The number of moles of a substance dissolved in in 1000 cm^3 of solution is called molality.** Gram molecular weight of a substance is dissolved in 1000 cc of water. It produces molal solution.

7. **Differentiate between acid and base.**

Ans: An acid is a substance that releases hydrogen ions (H^-) when dissolved in water. A substance that releases hydroxyl ions (OH^-) when dissolved in water is called base.

8. **What is pH? What is its relation with H^+ and OH^- ions?**

Ans: **The negative log (antilog) of hydrogen ion concentration is called pH.** Hydrogen and hydroxyl ions affect the chemical reactions in the cells. The higher the concentration of hydrogen ions (H^+), the more acidic the solution. The higher the concentration of hydroxyl (OH-) ions, the more basic (alkaline) the solution.

9. **What is buffer? Give one example.**

Ans: The substance which resists change in pH is called buffer. Its example is sodium bicarbonate.

10. **What are acidosis and alkalosis?**

Ans: An increase in acidity causes **acidosis**. The decrease in acidity causes **alkalosis**.

10. **What are the uses of buffer in bacterial culture?**

Ans: Bacteria are grown in culture medium in microbiological labs. Bacteria produce acids during reproduction. It changes the pH of the medium. The buffers are added to these media. It stabilizes the pH.

11. **What are colloidal solution and colloidal systems?**

Ans: A heterogeneous mixture in which solute particles are larger than molecules or ions but cannot be seen by naked eye is called colloidal solution. A system which shows propterties of colloidal solution is called colloidal system.

12. **What are dispersed and dispersion medium in colloidal solution?**

Ans: The solvent is called the **dispersion medium** in a colloidal solution. The solid solute particles are called **dispersed medium** in colloidal solution.

13. Differentiate between sol and gel.

Ans: A system composed of non-viscous colloidal solution is called sol. For example milk. A system composed of viscous colloidal solution is called gel. For example butter.

14. Differentiate between Lyophilic Systems and Lyophobic Systems.

Ans: The system in which dispersed phase and liquid dispersion medium attract each other is called lyophlic systems. The systems in which the dispersed phase and liquid dispersion phase repel each other is called lyophobic systems.

15. What is adsorption? Give its relation with colloidal solution.

Ans: **The tendency of molecules and ions to adhere to the surface of certain solids or liquids is called adsorption.** Colloidal particles show a high tendency of adsorption. Thus, colloidal systems provide a large surface area for adsorption of molecules and ions.

16. What is Tyndall cone?

Ans: colloidal particles scatter light. This is called Tyndall effect. The path of light appears as a cone. It is known as **Tyndall cone.** This property helps to detect the presence of colloidal particles.

17. What is role of colloidal solution in Cyclosis and amboeid movements?

Ans: The cyclosis occurs due to phase reversal of colloidal property. The cyclosis usually occurs in sol phase. Amoeboid movements in amoeba occur due to colloidal properties.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. **Mixing of table salt in water makes:**

(a) Mixture (b) Compound (c) Colloidal (d) Solution

2. **Which of the followings is electrolyte?**

(a) glucose (b) NaCl (c) sugar (d) Ether

3. **For example 10 gm of sodium chloride is added in 90 gm of water. This solution is:**

(a) 10% (b) 50% (c) 90% (d) 100%

4. **The number of moles of a solute per liter of a solution is**

(a) Molality (b) Normality (c) Molarity (d) None

5. **The number of moles of a substance dissolved in in 1000 cm^3 of solution is:**

(a) Molality (b) Normality (c) Molarity (d) None

6. **A substance that releases hydrogen ions (H^+) is:**

(a) Acid (b) Salt (c) Alkali (d) Base

7. **Which of the followings is not acidic pH?**

(a) 5 (b) 4 (c) 7 (d) 1

8. **Which of the followings acts as natural buffer?**

(a) NaCl (b) Na_2CO_3 (c) $NaHCO_3$ (d) $CaCl_2$

9. **The pH of blood remains at:**

(a) 4.3 (b) 7.35 (c) 9.23 (d) None

10. Which of the followings is gel?

(a) Milk (b) butter (d) paint (d) none

11. The tendency of molecules and ions to adhere to the surface of certain solids or liquids is called.

(a) absorption (b) diffusion (c) adsorption (d) None

12. Which of the followings is colloidal solution?

(a) Milk (b) Sugar in water (d) Water (d) Silk

Answers

1. (d) 2. (b) 3. (a) 4. (c) 5. (a) 6. (d) 7. (c) 8. (c) 9. (b) 10. (b) 11. (c) 12. (a)

Fill in blanks

1. A homogeneous mixture of two or more substances is called _____.
2. A solution in which more solutes cannot be dissolved is called ________ solution.
3. A saturated solution that can dissolve more solute when the temperature is increased is called solution.
4. The substances that conduct electric current in aqueous solution are called ___________.
5. The process of decomposition of electrolytes into its ions is called _________.
6. The number of moles of a solute per ________ of a solution is called molarity.
7. A gram molecular weight of a substance is dissolved in water to make exactly one liter of solution at 20 °C. It called a _______ solution (M).
8. The number of moles of a substance dissolved in ________cm^3 of solution is called molality.
9. Gram molecular weight of a substance is dissolved in 1000 cc of water. It produces _________ solution.
10. An ________ is a substance that releases hydrogen ions (H^-) when dissolved in water.
11. A substance that releases hydroxyl ions (OH^-) when dissolved in water is called _________.
12. The negative log (antilog) of hydrogen ion concentration is called _________.
13. The substance which resists change in pH is called ______.
14. An increase in acidity causes __________.
15. A heterogeneous mixture in which solute particles are larger than molecules or ions but cannot be seen by naked eye is called ___________ solution.
16. The system in which dispersed phase and liquid dispersion medium attract each other is called ________ systems.
17. The systems in which the dispersed phase and liquid dispersion phase repel each other is called ________ systems.
18. The tendency of molecules and ions to adhere to the surface of certain solids or liquids is called _________.
19. Carbonic acid dissociates to form hydrogen ion and __________ ion.
20. The negative ______ of hydrogen ion concentration is called pH.
21. A substance that releases hydroxyl ions (OH^-) when dissolved in water is called ________.
22. The process of decomposition of __________ into its ions is called electrolysis.
23. ____ of sodium chloride is added in 90 gm of water. It is called 10% solution.
24. A _________ solution has equal number of hydrogen ion and hydroxyl ions.
25. Buffers are mixture of weak acids and their salts of strong _______.
26. An increase in acidity causes __________.
27. The decrease in acidity causes __________.

Answers

1. solution
2. saturated
3. supersaturated
4. electrolytes
5. electrolysis
6. liter
7. molar
8. 1000
9. molal
10. acid
11. base
12. pH
13. buffer
14. acidosis
15 colloidal
16. lyophlic
17. lyophobic
18. Adsorption
19. bicarbonate
20. Log
21. base
22. electrolytes
23. 10 gm
24. neutral
25. bases
26. acidosis
27. alkalosis

True/False

1. A heterogenous mixture of two or more substances is called solution.
2. A saturated solution that can dissolve more solute when the temperature is increased is called supersaturated solution.
3. The substances which do not conduct electric current are called electrolytes.
4. The number of moles of a substance dissolved in $1000\ cm^3$ of solution is called molality.
5. The acids and bases can neutralize one another to form a solution and water.
6. The substance which resists change in pH is called colloidal.
7. A heterogeneous mixture in which solute particles are larger than molecules or ions but cannot be seen by naked eye is called colloidal solution.
8. The system in which dispersed phase and liquid dispersion medium attract each other is called lymph systems.
9. The tendency of molecules and ions to adhere to the surface of certain solids or liquids is called adsorption.
10. Protoplasm shows buffering property. It is due to solution nature of protoplasm.
11. The cyclosis usually occurs in sol phase. Amoeboid movements in amoeba occur due to colloidal properties.
12. The conversion of a sol to a gel is called solation.
13. Carbonic acid dissociates to form hydrogen ion and bicarbonate ion.
14. The negative log (antilog) of hydrogen ion concentration is called pH.
15. A substance that releases hydroxyl ions (OH^-) when dissolved in water is called acid.
16. The process of decomposition of electrolytes into its ions is called electrolysis.
17. 10 gm of sodium chloride is added in 90 gm of water. It is called 0.1% solution.
18. A neutral solution has equal number of hydrogen ion and hydroxyl ions.
19. Buffers are mixture of strong acids and their salts of strong bases.
20. An increase in acidity causes acidosis.
21. The decrease in acidity causes acidosis.

Answers

1. F. homogeneous
2. T
3. F. non – electrolytes
4. T.
5. F. Salt
6. F. Buffer
7. T
8. F. Lyophilic
9. T
10. F. colloidal
11. T
12. Gelation
13. T
14. T
15. Base
16. T
17. F. 10%
18. T
19. F. weak
20. T
21. Alkalosis

Chapter 2

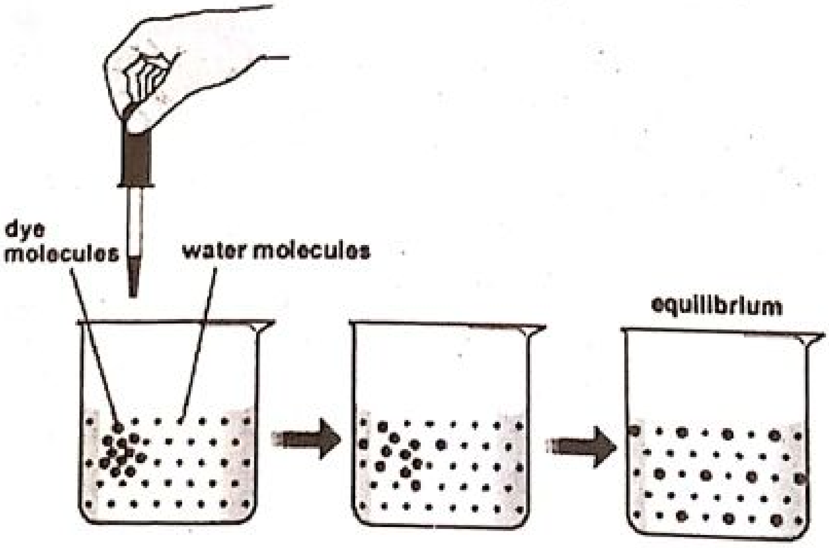
DIFFUSION, OSMOSIS, ABSORPTION, TRANSLOCATION & TRANSPIRATION

Syllabus
1. Diffusion, imbibitions, osmotic and osmotic components
2. Water relations, (water potential, pressure potential, matric potential)
3. Absorption and translocation of water.
4. Transpiration, factor affecting transpiration
5. Stomatal structure and function (Stomatal physiology)

DIFFUSION

The movement of molecules from higher concentration to lower concentration is called diffusion. Diffusion occurs down the concentration gradient. It is a spontaneous process. Diffusion continues till dynamic equilibrium is achieved. It follows laws of thermodynamics. But it is a very slow process.

The rate and the direction of diffusion of different substances depend upon the difference in their concentration at different points. It is independent of the presence of other substances.



Examples

1. Oxygen is utilized and carbon dioxide is removed during respiration in a leaf. This

CO_2 collects in the intercellular spaces of the leaf. Carbon dioxide diffuses from the intercellular spaces into the outer air. But oxygen diffuses in the reverse direction.

2. Petrol and perfume are volatile liquids. Camphor and naphthalene balls are volatile solids. They diffuse in the same way. Their odour can be detected from some distance away.
3. A crystal of copper sulphate is placed in a beaker of water. It slowly dissolves. The surface of the crystal has greater concentration. But other parts of water have lesser concentration of copper sulphate. Therefore, the molecules of copper sulphate move from surface to other part. After some time the crystal disappears. Its molecules are evenly distributed throughout the surrounding liquid.

Factors affecting the diffusion

Following factors are responsible for diffusion:

1. Chemical potential

All the three states of matter solid, liquid and gas are made up of molecules. These molecules possess **kinetic energy or free energy** at temperature above –273°C. **The total kinetic energy of the molecules is called chemical potential.** Therefore, the molecules are in constant motion. They collide with one another. Thus molecules of a substance try to move from the region of their higher concentration or higher kinetic energy to the region of their lower concentration or lower kinetic energy. Thus diffusion directly depends on the chemical potential. Temperature and pressure affects the chemical potential. Therefore they also affect the rate of diffusion.

2. Density

The density of the diffusion medium also affects the rate of diffusion. The molecules of diffusion medium produce resistance to the diffusing particles. Greater the density of the medium, greater will be this resistance. Therefore, it slower the rate of diffusion. For example, diffusion of sugar molecules in water. Sugar dissolves rapidly in hot water than in cold water. The water molecules become less dense at higher temperature. Therefore, its resistance to the diffusing sugar molecules decreases. Thus the sugar molecule can diffuse through water with greater velocity. The density of a substance depends upon its molecular weight and the distance between the molecules. The distance between the molecules is the greatest in gases. Therefore, gases have the lowest density. The solids have least distances. Therefore, they have higher density and low rate of diffusion.

Graham's law

It states that the rates of diffusion of gases are inversely proportional to the square roots of their densities. Graham's law is applied on the diffusion of gases.

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

Where r_1 and r_2 are the rate of diffusion and d_1 and d_2 are their densities.

3. Diffusion pressure

The pressure exerted by the diffusing particles is known as diffusion pressure. This pressure is directly proportional to the concentration or the number of diffusing particles. Greater the concentration of diffusing particles in a system, the greater is their diffusion pressure. For example, the diffusion-pressure of copper sulphate particles is the highest near the dissolving crystal. But it is the lowest in the other regions. Therefore, the particles of copper sulphate diffuse from the region of their greater diffusion pressure to the region of their lesser diffusion pressure.

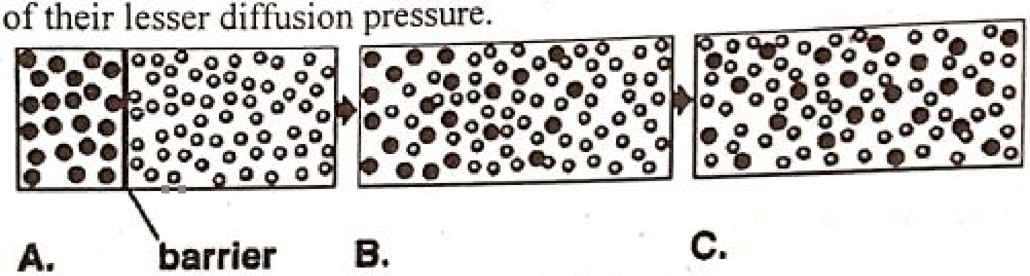


Fig: Process of diffusion

Importance of diffusion in plants

Diffusion is very important process in plants.

1. Plants transfer food particles from phloem and water particles from xylem through diffusion.
2. They get carbon dioxide and release oxygen through diffusion. This diffusion occurs through stomata and mesophyll cells.
3. Photosynthesis also includes diffusion in a number of steps.
4. Root absorbs water and salts from the soil. This water is transferred from roots to leaves through the process of diffusion.
5. Fungi absorb digested food by the process of diffusion.

IMBIBITION

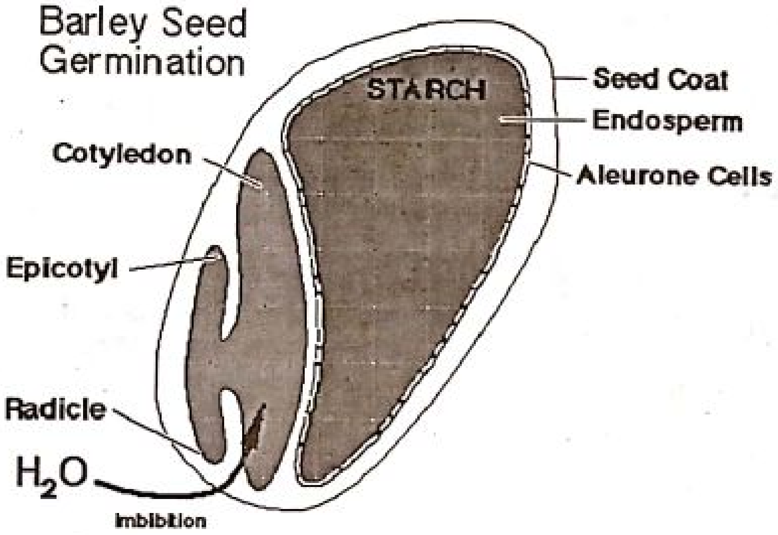
The special type of diffusion in which an imbibant absorbs water on its surface without dissolving in it is called imbibition. Water movement is along a concentration gradient in imbibition. Therefore, imbibition is a special type of diffusion. In imbibition, water is absorbed by solids-colloids. It causes an enormous increase in volume. Water potential gradient between absorbent (imbibant) and liquid imbibed is essential for imbibition. Imbibition occurs when a wetting fluid displaces a non-wetting fluid.

Imbibant (adsorbent) is a hydrophilic surfaces like protein, starch or clay. Different types of organic substances have different imbibing capacities. Proteins have a very high imbibing capacity then starch and cellulose. Therefore, proteinaceous pea seeds swell more on imbibition than starchy wheat seeds. The force generated by the imbibants is called **imbibition pressure or metric potential**. The metric potential is similar to solute potential. The direction of water movement is from a region of higher water potential to one of lower water potential. Hydrogen bonding is responsible for binding (adsorption) of water molecules to the hydrophilic surfaces.

Significance of imbibition

The insoluble, solid, hydrophilic protoplasmic and cell wall constituents absorb water by imbibition.

1. Dry plant material like dry wood is placed in water. It swells and its volume increases.



2. Dry pea seeds are placed in water. These also swell. It helps in the germination of seed.
3. If the imbibant is dried and then put in water, it can develop a high pressure (imbibition pressure). This pressure imbibes water. For example, imbibition occurs in the wooden door or window frame during humid weather or rainy season. It becomes difficult to close door after imbibition.
4. Imbibition also maintains genetic clock that controls circadian rhythms in *Arabidopsis thaliana* and other plants.
5. The grafted tissues during grafting of tissues get water through imbibition.
6. Imbibition has also role in absorption of water by root at initial stages.

OSMOSIS

The movement of solvent molecules from the region of higher concentration to the region of lower concentration through semi permeable membrane is called osmosis.

Demonstration of osmosis

A thistle funnel is filled with a concentrated solution of sucrose. Its mouth is closed with a rubber membrane. The thistle funnel is inverted in beaker containing water. The mouth of the thistle funnel dips under water. The level of sugar solution is marked. Again note down the level of sugar solution after about 24tours. It is observed that the level of sugar solution in the thistle funnel moved down ward. It shows that osmosis occur through the semi permeable membrane. After some time, the concentration of sugar molecules and water molecules will be the same both in the beaker and the thistle funnel. Therefore, the osmosis will stop.

Factors affecting the osmosis

1. Osmotic pressure (OP)

The maximum pressure that develops when a solution is separated from its solvent by a semi permeable membrane is called osmotic pressure. It is also called osmotic potential. It moves the solvent inward.

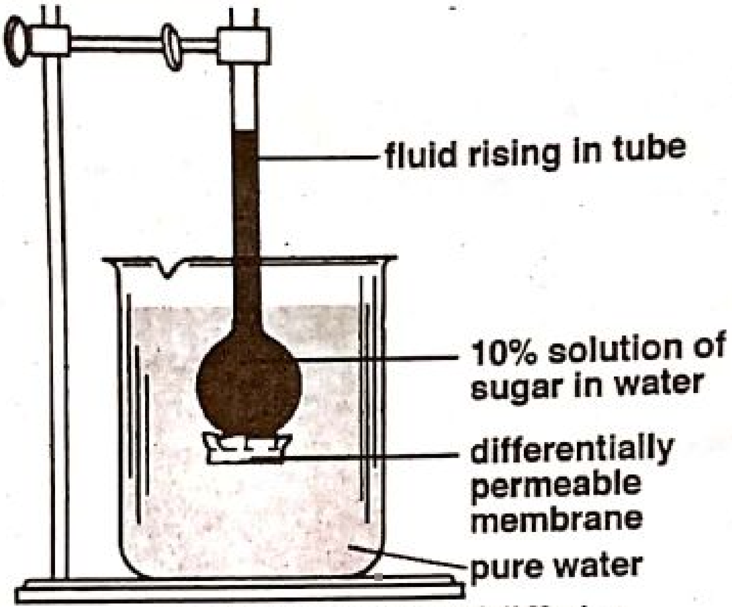

fluid rising in tube
10% solution of sugar in water
differentially permeable membrane
pure water

Fig: Demonstration of diffusion

2. Diffusion pressure (DP)

The diffusion pressure of water is more than the diffusion pressure of solution. Therefore, osmosis occurs from higher diffusion pressure to lower diffusion pressure of solvent. The difference of diffusion pressures of solvent molecules and its solution is called **diffusion pressure deficit (DPD)**. Osmosis occurs only when the value of DPD is more than zero.

3. Turgor pressure (TP)

The pressure exerted by the cell sap on the cell wall of plant cell is called turgor pressure. It opposes the process of osmosis. Thus there is following relations between DPD, OP and TP

$$DPD = OP - TP$$

Mechanism of osmosis

Osmosis is the movement of a solvent across a semi-permeable membrane. It is movement toward a higher concentration of solute. In biological systems, solvent is typically water. But osmosis can occur in other liquids and even gases.

Let we submerge a cell in water. The water molecules pass through the cell membrane from an area of low solute concentration to high solute concentration. For example, if the cell is submerged in saltwater, water molecules move out of the cell. If a cell is submerged in freshwater, water molecules move into the cell.

In some cases, membrane has a volume of pure water on both sides. Now water molecules pass in and out in each direction at exactly the same rate. There is no net flow of water through the membrane.

Old concepts

According to old concepts, two mechanisms were responsible for driving osmosis. These are:

a) **Dilution of water by solute.** Thus there is lower concentration of water on the higher solute concentration side of the membrane. Therefore a diffusion of water along a concentration gradient

b) **Attraction of solute for water.** It causes less free water on the higher solute concentration side of the membrane. Therefore, net movement of water toward the solute.

Both these mechanisms are not well supported by experimental evidences. Therefore, these are note accepted as true mechanisms of osmosis.

New concept

According to new concepts, Osmosis, unlike diffusion, requires a force. Osmotic pressure is the main support for osmosis in many plants. The osmotic entry of water raises the turgor pressure. Turgor pressure is exerted against the cell wall. Water continues to enter until turgor pressure become equal the osmotic pressure. Now it creates a steady state.

a) We place a plant cell in a solution that is hypertonic relative to the cytoplasm. Now water moves out of the cell. The cell shrinks. Therefore, cell becomes **flaccid**. In extreme cases, the cell becomes plasmolyzed. The cell membrane disengages with the cell wall due to lack of water pressure on it in **plasmolyzed** cell.

b) Now we place a plant cell in a solution that is hypotonic relative to the cytoplasm. Now water moves into the cell. The cell swells to become **turgid**.

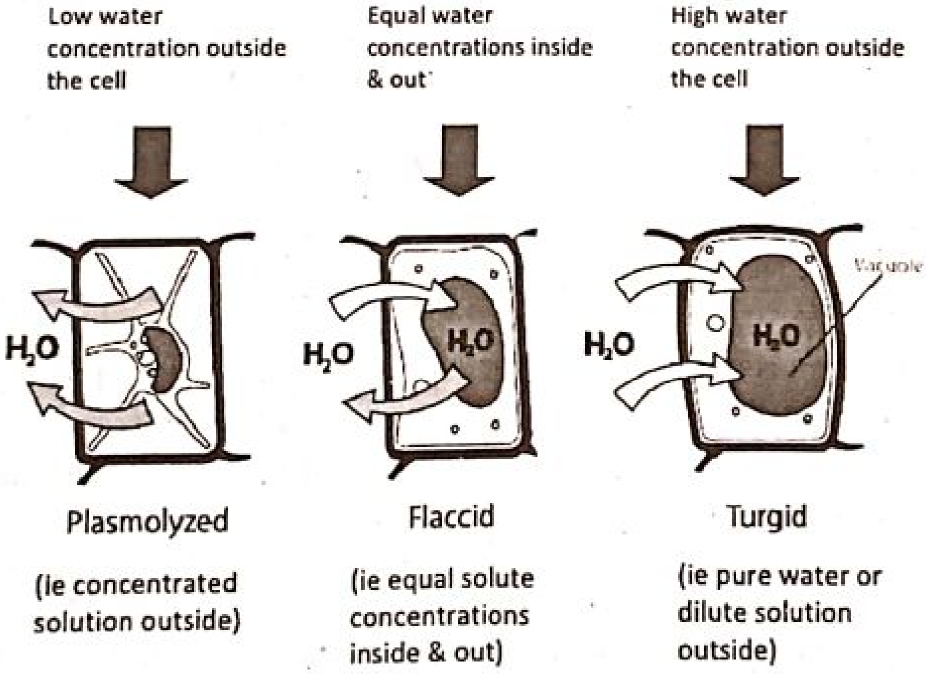

Low water concentration outside the cell
Equal water concentrations inside & out
High water concentration outside the cell
Vacuole
H_2O
H_2O
H_2O
H_2O
H_2O
Plasmolyzed
(Ie concentrated solution outside)
Flaccid
(ie equal solute concentrations inside & out)
Turgid
(ie pure water or dilute solution outside)

Fig: Osmosis in plant cells

Biological role or significance of osmosis

1. A large vacuole is present in plant cells. It is bounded by tonoplast. Water move in and out of vacuole through tonoplast by osmosis.
2. Osmosis is responsible for the ability of plant roots to draw water from the soil. Plants concentrate solutes in their root cells by active transport. Now water enters the roots

by osmosis.

3. Root pressure is caused by process of osmosis of water and mineral into root. It is responsible for ascent of sap in many smaller plants.
4. Osmosis is also responsible for controlling the movement of guard cells. Guard cells absorb water by osmosis and become turgid. Thus stomata between is opened. They lose water by osmosis. Thus they become flaccid. Therefore, stomata are closed.
5. Osmosis also has role in preservation of foods like jam, jellies pickles etc. These foods are kept in highly concentrated solutions of sugar or salts. Bacterial cells lose water osmotically in this medium. It becomes dehydrated and died.
6. Osmosis is a colligative property of solution. This property depends upon concentration of solvent. Therefore, osmosis is used to determine concentration and molecular weight of solute.
7. Reverse osmosis process is used in water filtration plants.

Difference between Osmosis and Diffusion

Osmosis	Diffusion
1. It involves movement of solvent molecules.	1. It involves movement of solute molecules.
2. Molecules of move from lower concentration of solute to higher concentration of solute.	2. Molecules moves from higher concentration of solute to lower concentration of solute.
3. It occurs only across semi-permeable membrane.	3. Semi-permeable membrane is not involved in it.
4. Examples: Shrinkage of potato slices when placed in concentration solution of sucrose solution.	4. Example: Spreading of ink in glass of water.

WATER RELATIONS

WATER POTENTIAL (Ψ)

The chemical potential of water is called water potential. The total kinetic energy of the molecules is called water potential. It is chemical free energy of water. The chemical potential of water depends on the number of water molecules. Thus it is expressed as energy per mole of water molecule.

The chemical free energy of water in its purest form is also called water potential. Purest form of water means there are no other molecules in it. The chemical energy is maximum of pure water. Its value is given as 0 bars. Addition of solutes to pure solvent decreases the chemical free energy of pure water. Certain amount of energy of a number of water molecules is used for binding to the surface of solutes. So the total value of water potential of a solution is less than zero. The chemical potential of pure water is taken as zero.

The kinetic energy of the molecules increases with the increase of temperature. More molecules are converted into vapours. It increases the free energy. Thus it also increases the water potential. Water molecules moves from the region of higher water potential to the region of lower water potential.

The water potential is expressed in bars. One bar = 0.987 atm. There are following three components of water potential. These are metric potential, solute potential and pressure.

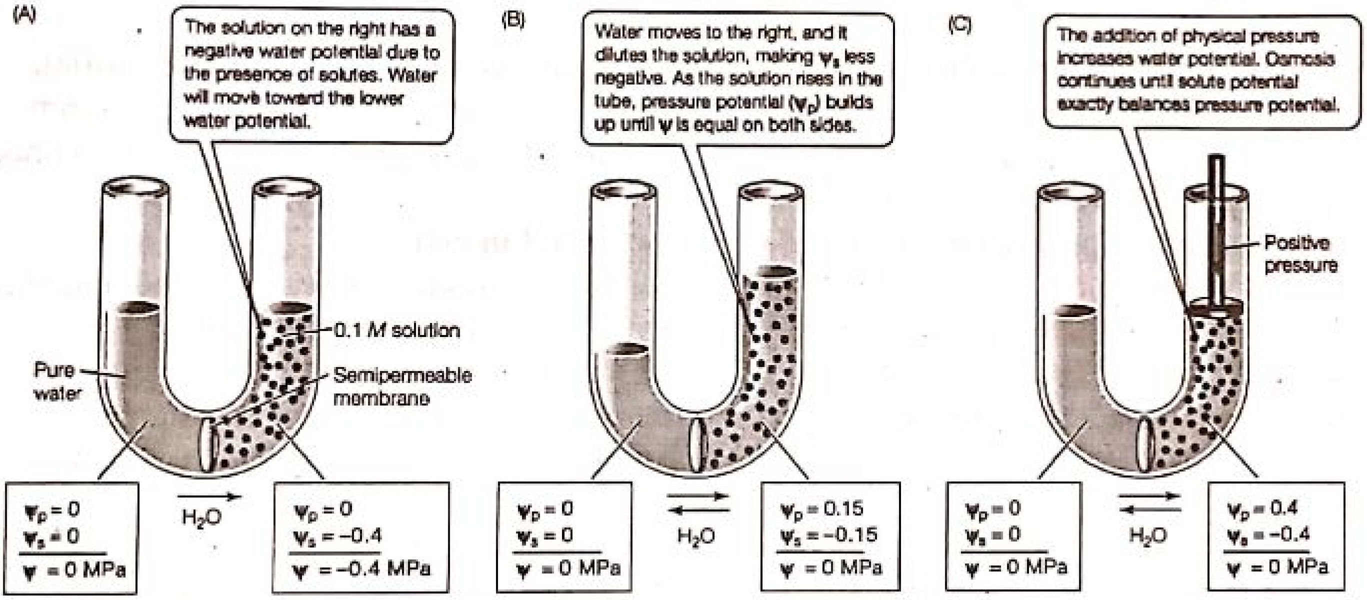

(A)
The solution on the right has a negative water potential due to the presence of solutes. Water will move toward the lower water potential.
0.1 M solution
Pure water
Semipermeable membrane
$\psi_p = 0$
$\psi_s = 0$
$\psi = 0$ MPa
H_2O
$\psi_p = 0$
$\psi_s = -0.4$
$\psi = -0.4$ MPa
(B)
Water moves to the right, and it dilutes the solution, making ψ_s less negative. As the solution rises in the tube, pressure potential (ψ_p) builds up until ψ is equal on both sides.
$\psi_p = 0$
$\psi_s = 0$
$\psi = 0$ MPa
H_2O
$\psi_p = 0.15$
$\psi_s = -0.15$
$\psi = 0$ MPa
(C)
The addition of physical pressure increases water potential. Osmosis continues until solute potential exactly balances pressure potential.
Positive pressure
$\psi_p = 0$
$\psi_s = 0$
$\psi = 0$ MPa
H_2O
$\psi_p = 0.4$
$\psi_s = -0.4$
$\psi = 0$ MPa

Fig: Water potential, matric potential, solute potential and pressure potential

(a) Matric potential (ψ_m)

The decrease in the water potential due to affinity of water molecules with the colloidal substances (protoplasm and cell wall) is called matric potential. It is represented by **ψm**. The water molecules are tightly bound on the colloidal surface. It reduces the movement of water molecules. Therefore, water potential decreases. Matric potential is very high in dry seed. It is -100 to -200 bars in it. It is also very high in clay soil particles. Thus the chemical potential of the seeds and soil depend upon matric potential.

(b) Solute potential (ψ_s) or osmotic potential or Osmotic Pressure

The decrease in water potential due to dissolution of solute molecules or ions in water is called solute potential. The solute molecules start colliding with the water molecules. Therefore, water potential is reduced. It is also called osmotic potential or osmotic pressure (OP). It is expressed as bars with negative sign.

The movement of water into the cell (endosmosis or plasmolysis) mostly depends upon the concentration of solute. The solute may be mineral salts, proteins, carbohydrates, fatty acids etc. These contribute to the osmotic potential or osmotic concentration. It contributes to the osmotic pressure. Higher the concentration of solutes, higher is the osmotic pressure and vice-versa.

A solution is made up of a solvent within. The solutes are dissolved or present in soluble form. Thus solution may be dilute solution or concentrated solution. There is kinetic movement and collision of the solute molecules. Therefore, concentration of solutes exerts a pressure.

This pressure is osmotic pressure. Hence a dilute solution exhibits lower osmotic pressure. But concentrated solution shows higher osmotic pressure or osmotic potential.

(c) Pressure potential (ψ_p)

The turgor pressure (TP) exerted by the vacuole is called pressure potential. Its value is positive. Thus pressure potential increases the water potential. It varies from +4 to +5 bars during day time. But it is +10 to +15 bars at night. The young cells are without vacuoles. Therefore, it is zero in these cells.

Interrelationships of components of water potential in cell

1. Water present in cell is never pure. It always contains some dissolved minerals, sugars and organic acids. Therefore, it always has some solute potential.
2. Similarly, water is present in the vacuole. It always exerts some pressure potential.
3. Cells always have some colloidal substances. They exert some matric potential.

Thus the water potential of the cell is the sum of different component of potentials as follows.

Water potential = Solute potential + Pressure potential + Matric potential

Ψ (water) $= \Psi_s + \Psi_p + \Psi_m$

But matric potential is negligible in cell. Therefore,

Ψ (water) $= \Psi_s + \Psi_p$

Methods of Measurement of Water Potential

Different methods are used to measure water potential:

1. Vapour pressure method

It is a most simple method. It is most commonly used. In this case, plant tissue is placed in a small closed volume of air. Water potential of air is allowed to become equilibrium with water potential of the tissue. Now vapour density or humidity of air is determined. Then water potential is calculated from it.

2. Tissue volume method

A sample of tissue like potato tuber cylinders is taken. It is placed in a series of sucrose solutions. These solutions have different concentrations. Potato cylinders are weighed before and after immersion. Tissue volume does not change in one the solution. There is no gain or loss in water in this solution. The water potential of this solution is equal to the water potential of the tissue.

3. Falling drop method or Chardakov method

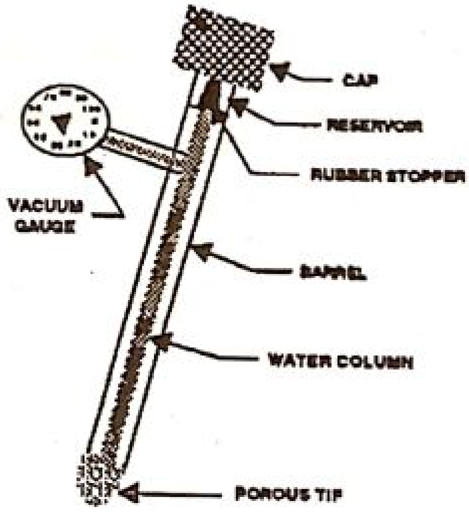
1. Two graded series of sucrose solutions are prepared. Their concentration is ranging from 0.15 to 0.50 molal. Solutions are placed in two test tube sets.
2. Plant tissue is placed in each test tube of first series. It is called **test series.**
3. A drop of methylene blue is mixed into each solution of second series. It is called **control series.**
4. After half an hour the tissue is removed from each tube. A drop of respective control series solution is introduced below the surface of its corresponding test solution.
   - The drop may rise in the tube. It means drop is lighter. Thus tissue containing

solution is more concentrated. Here water from the solution entered into the tissue.

- The drop may fall. Here test solution is lighter. Here water leaves the tissue.
- The drop may remain suspended. Here there is no rise or fall. Here water potential of the tissue is equal to solution. It is called **null point**. It gives water potential of the tissue.

4. By using tensiometer

Tensiometer tube contains a pool of pure, free water. This reservoir is connected (through a permeable membrane to a soil sample. Water moves from the reservoir to the soil until its energy is equal on both sides of the membrane. That creates a vacuum in the tube. The tensiometer uses a negative pressure gauge to measures the strength of that vacuum. It describes water potential in terms of pressure.



Application of water potential

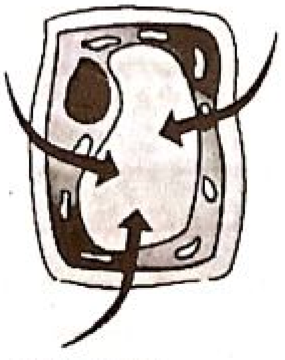
There are following applications of water potential:

1. Water potential can be used to measure tendency of water to move between any two systems.
2. Water potential can also be used for movement of water from soil to root, from leaf to air, from air to soil. Water flows fast along the steep potential gradient (higher to lower).

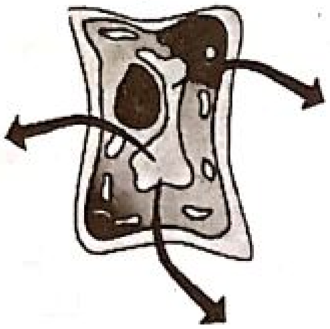
PLASMOLYSIS AND PRESSURE POTENTIAL

Plasmolysis

The shrinkage of protoplast due to exosmosis of water is called plasmolysis. When a living cell is placed in a solution with lower water potential than the cell, the cell loses water. This cell is called **plasmolysed cell.** If this plasmolysed cell is placed in the distilled water, the water molecules will move from distilled water into the cell. This cell becomes **deplasmolysed.**



TURGID CELL:
water enters by osmosis,
vacuole swells and
pushes against cell wall



FLACCID CELL:
water lost from cell,
vacuole shrinks,
cell loses shape

Incipient plasmolysis

The point at which plasmolysis is about to take place is called incipient plasmolysis. The protoplast stops exerting the pressure against the cell wall at incipient plasmolysis. So the cell becomes flaccid.

Plasmolysis and Pressure potential

If a plasmolysed cell is placed in the distilled water, the water enters into the cell by endosmosis. The distal water has higher water potential than the cell. So the volume of the protoplast is increased. It starts exerting pressure against the wall of the plant cell. The pressure exerted by the protoplast against the cell wall is called **pressure potential**. The cell wall of the plant cells is rigid. The pressure potential increases due to endosmosis. So the cell becomes turgid. Maximum pressure potential is achieved when a cell is placed in pure water or distilled water. It causes full turgidity.

ABSORPTION OF WATER

SOIL

The complex composite mass made up of both inorganic and organic, components containing water and air is called soil. There are different amount of various components of soil. Their amount and depends upon the nature of the soil, its depth and the state of its irrigation. The ordinary garden soil has the following composition by volume:

Material	Composition
Mineral matter	40 per cent
Organic matter	10
Water	25
Air	25

Inorganic Minerals

The inorganic component of the soil consists of mineral particles. They have different sizes. They are formed by the breaking of rocks. This process is called **weathering**. Weathering is caused by frost, snow, rain and wind. The rocks from which the mineral matter is derived are either limestone or sandstones. Limestone produces chalky soil and sand stones produces sandy soil.

Diameter of Particles in mm	Type of soil
2.00 upwards	Gravel
2.00—0.20	Coarse sand
0.20—0.02	Fine sand
0.02—0.002	Silt
below 0.002	Clay

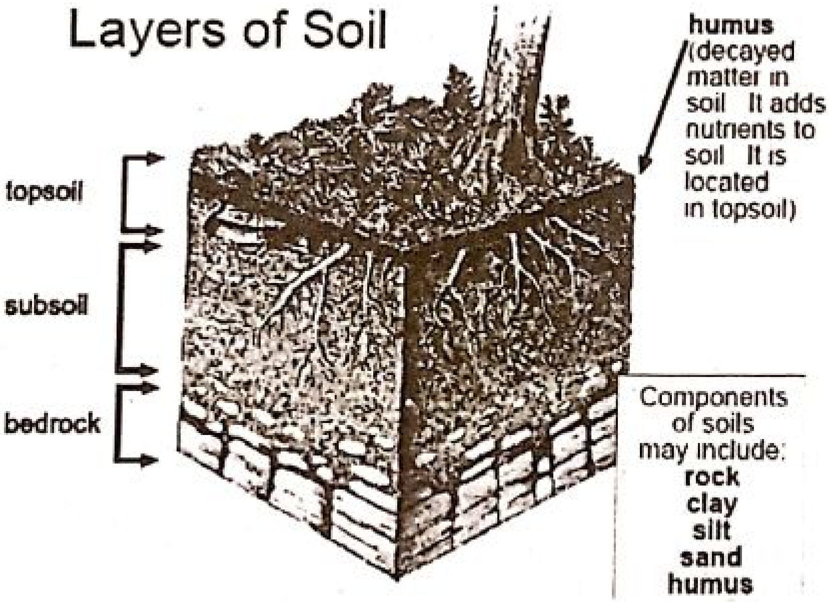
The characteristics of a soil depend mainly on the texture or the size of the mineral particles:

Texture of soil

Relative proportion of the soil particles size is known as soil texture. There are following types of textures of soil:

1. **Gravel:** It is composed of large minerals. Size of its particles is more than 2.00mm.

2. **Sand:** Soils in which the mineral matter consists mainly of sand particles are called sandy soils. Sandy soils have little water absorbing properties and are loose, dry and poor in salutes. However, large interspaces are present between the sand particles. Thus water and air can move freely.
3. **Loam:** A soil in which the sand, silt and clay particles are present in equal proportions is called loam. It is most suitable for plant growth. A loam soil in which sand particles predominate is called sandy loam and the one in which clay particles dominates is called sandy loam.
4. **Silt:** Size of its particles is less than sand.
5. **Clay:** The soil consists mainly of clay particles are called clayey soils. The clay particles are mostly of colloidal nature. They possess high water holding properties. But they have small interspaces between them. Therefore, water and air cannot move freely among these particles.


Layers of Soil
humus (decayed matter in soil It adds nutrients to soil It is located in topsoil)
topsoil
subsoil
bedrock
Components of soils may include:
rock
clay
silt
sand
humus

Profile of soil

The arrangement of soil particles in layers is called soil profile. The composition and appearance of the soil changes from the surface downwards. Soil shows distinct layers.

1. **A – Horizon:** The uppermost layer is called A-horizon. It contains finer rock particles. It is also rich in organic matter.
2. **B – Horizon:** It is present immediately below the B- horizon. It is made up of comparatively coarse mineral matter. It also contains some clay.
3. **C – Horizon:** It consists of the parent rock material or the mother earth.

Organic Matter

Soil also contains organic matter. **The organic matter formed by the decomposition of the dead plant is called humus.** Humus is dark in colour and light in weight. It is an essential constituent of all soils.

Humus and clay are the two colloidal components of the soil. They are closely associated with each other. Humus and clay form **colloidal complex** of the soil. The colloidal complex gives structure to the soil. It improves aeration of the soil. Thus it improves the water-holding capacity of sandy soils.

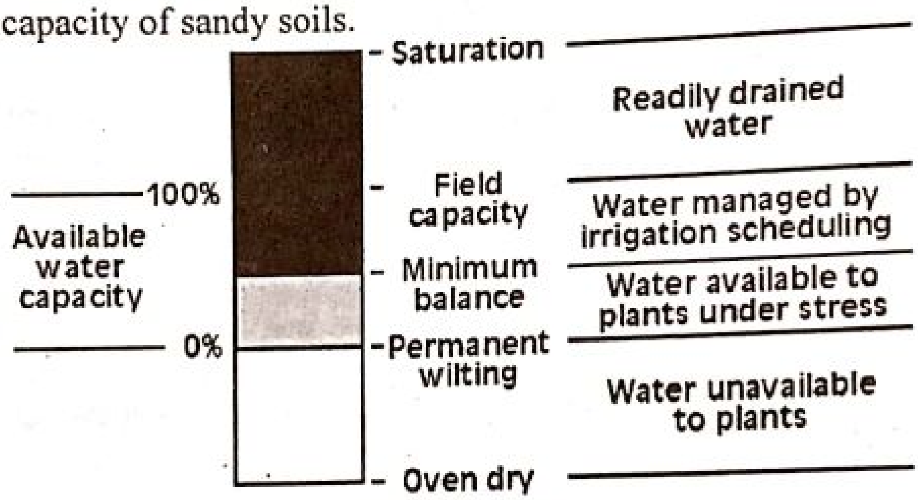


Fig: Soil water

Soil Water

Soil is a great reservoir of water. The amount of water contained in this reservoir varies greatly in different soils and under different conditions. Its amount in ordinary garden soil is about 25 per cent by volume. The principal source of soil water is rain. There are following type of water present in the soil:

1. **Run away water:** Some of the water drains away along the slopes after a heavy rainfall or irrigation. This is called run-away water. It is not available to the plant.
2. **Gravitational water:** Some of the water is absorbed by the soil and saturates its upper layers. It percolates downwards through the larger pores between the soils particles due to gravity. Finally, it reaches the water table. This is called the gravitational water. Gravitational. Water is also not available to the plant.
3. **Soil holding water:** Much of the rainwater is retained by the soil particles. It makes the soil wet. The amount of water retained by soil after the removal of excess water by gravitation is called **the field capacity** or **the water holding capacity** of the soil.
4. **Hygroscopic water:** Water adsorbed on the surface of soil colloids is called hygroscopic water. It is tightly held by soil. It forms very thin films. It is non-available to the plant.
5. **Capillary water:** The water which fills the spaces between the non colloidal smaller soil particles is called capillary water. It has the greatest importance for the plant. This water is available to plant. The plant absorbs this water through roots.
6. **Chemically combined water:** A small amount of water is bound to the molecules of some soil minerals by strong chemical bonds. It is also not available to the root. This is called chemically combined water.
7. **Water table:** The water level at some depth from the soil where all pore spaces are filled with water is called water table. It may be present from few feet to several hundred feet. Water rises from water table by capillary action. It is used by the plants.

Water availability for plants

1. **Field capacity of the soil:** The hygroscopic and capillary water forms the field capacity of soil. It is different for different types of soils. Field capacity varies from 5 to 35%. The clay soil has the highest field capacity.
2. **Wilting coefficient or permanent wilting point:** The amount of moisture left in the soil after a plant has permanently wilt is called wilting coefficient. Soil water is now empty for plant. More water must be added to the soil. Otherwise, the plant will die. The value of wilting coefficient depends upon the nature of the soil. It is lowest for the sandy soil. But it is highest for the clayey soil.

Soil air

The soil particles are irregular in size and shape. Therefore, interspaces are present between them. These interspaces are filled by air or partly by water. This soil air is essential for the proper growth of plant.

Soil organisms

Soil also contains many organisms. It is rich in algae, bacteria, fungi and soil fauna.

1. **Bacteria:** Bacteria are the most abundant in the soil. They play an important role in the soil formation. Some important soil bacteria are the ammonifying, nitrifying and nitrogen fixing bacteria.
2. **Fungi:** Bacteria and soil fungi decompose the organic compounds of dead plant. They convert them into humus.
3. **Animals:** Some soil animals are protozoa, earthworms, insects, and burrowing animals. The earthworms are especially important in loosening the soil. It improves aeration and movement of water.

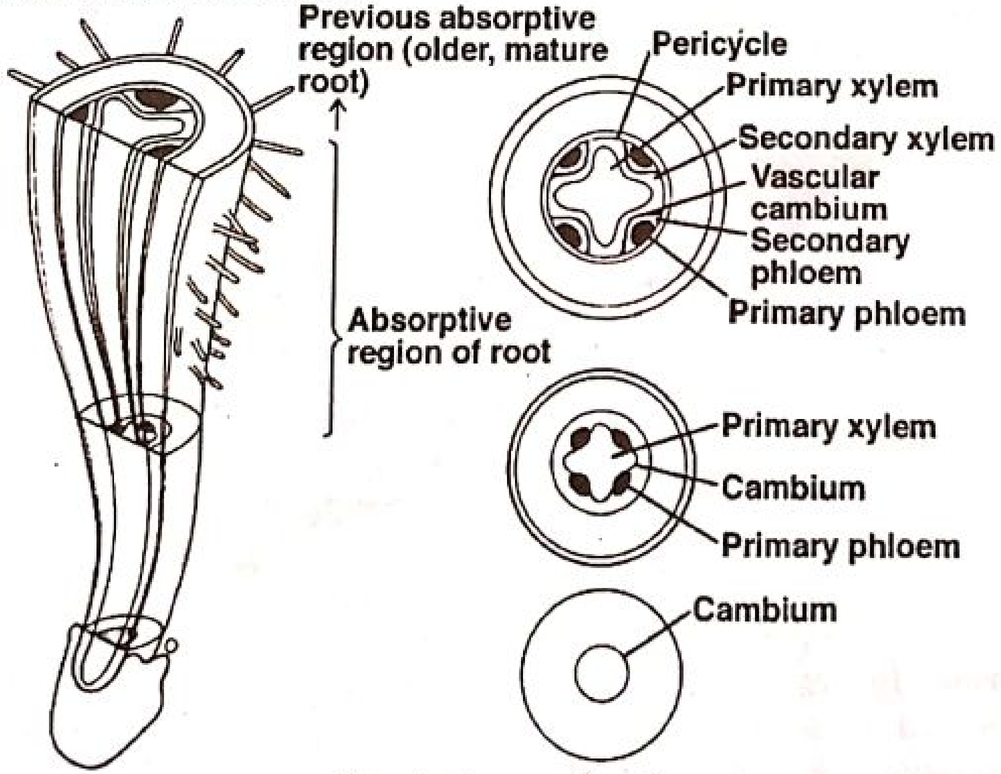


Fig: Anatomy of root

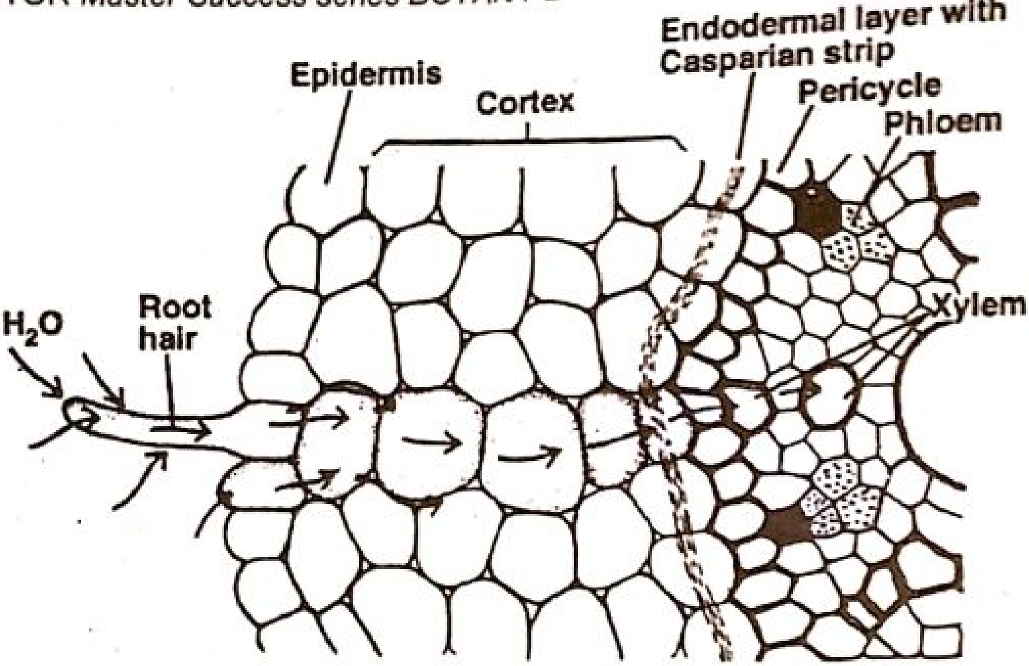


Fig: Root hair structure

ANATOMY OF ROOT

Root has following types of tissues:

1. **Stele:** The vascular tissue and the pericycle form a tube of conducting cells called stele. Xylems are present in the centre of the root. Xylems are composed of tracheids and vessels. The xylem of the root is continuous with the xylem tissue in the stem. The xylem tissues are surrounded by the phloem tissues. The xylem and phloem elements (vascular tissue) are surrounded by pericycle.

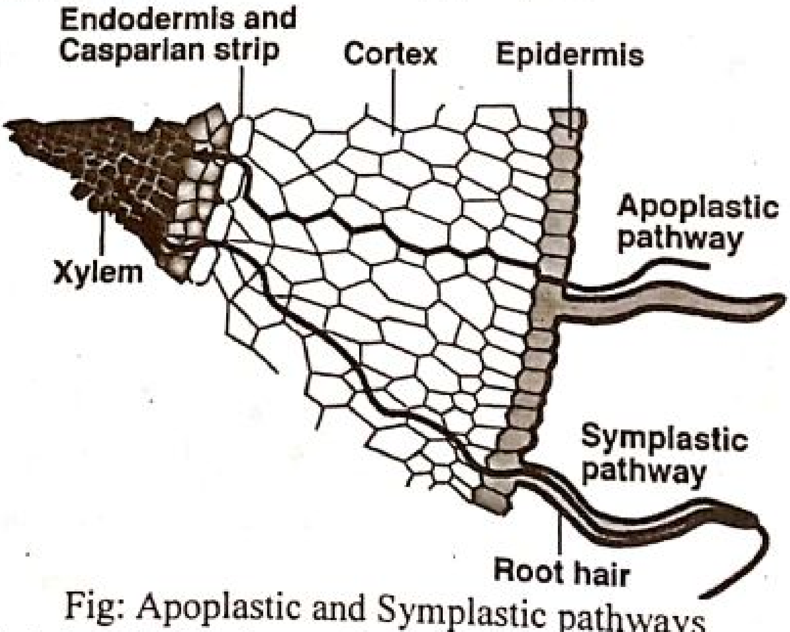
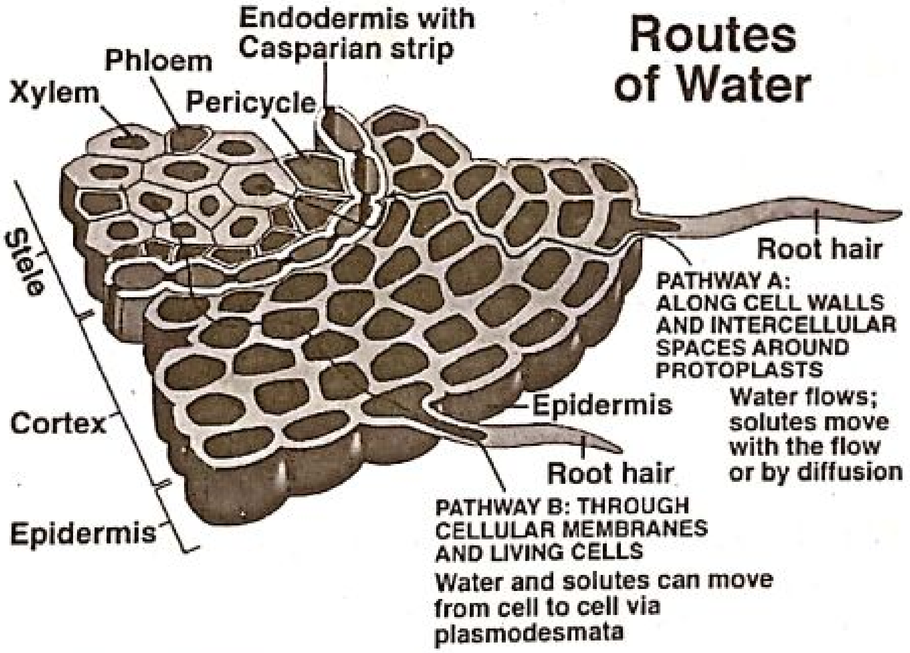


Fig: Apoplastic and Symplastic pathways

2. **Endodermis:** Endodermis is a layer of cells present outside the stele. The transverse and radial cell walls of endodermal cells have **Casparian strips**. These strips are characteristics cell wall thickenings. These are impregnated with **suberin**. Suberin is

impermeable to water. Therefore, the water with its dissolved substances cannot pass out of endodermal cells.

3. **Cortex:** Cortex is present outside the endodermis. It is composed of several layers of large thin-walled living cells. The intercellular spaces are present among these cells. The cell wall of cortical cells are highly permeable to water and its dissolved solutes.
4. **Epidermis and root hairs:** The cortex is surrounded by a layer of epidermis. They are flattened cells. The outer walls of root epidermal cells elongate. It forms thin-walled hair-like structures called **root hairs**. These root hairs spread in the soil particles. Most of the water enters through the root hairs and their associated epidermal cells.


Endodermis with Casparian strip
Phloem
Xylem
Pericycle
Routes of Water
Stele
Root hair
PATHWAY A: ALONG CELL WALLS AND INTERCELLULAR SPACES AROUND PROTOPLASTS
Epidermis
Water flows; solutes move with the flow or by diffusion
Cortex
Root hair
PATHWAY B: THROUGH CELLULAR MEMBRANES AND LIVING CELLS
Water and solutes can move from cell to cell via plasmodesmata
Epidermis

Water pathways through root

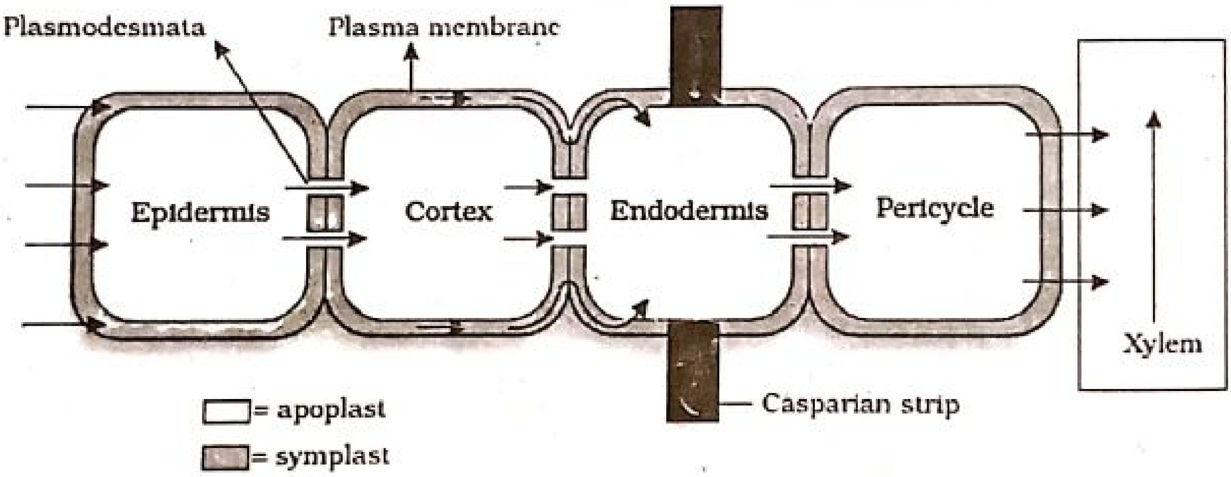
There are three water pathways through root:

1. **Apoplast pathway:** The movement of water molecules through the adjacent cell walls is called apoplast pathway. The interconnected cell walls and water filled xylem elements form single system called apoplast. The apoplast is continuous throughout the plant except for the Casparian strips in the roots.
2. **Symplast Pathway:** The movement of water through the protoplast of the plant cells is called symplast pathway. The interconnected protoplasts in the plant are called symplast. The cytoplasm of the neighbouring cells is linked by the plasmodesmata in the cell walls.
3. **Vacuolar Pathway:** The movement of water molecules from vacuole to vacuole through neighbouring cells is called vacuolar pathway.

Fig: Passage of water through endodermis

Apoplast pathway	Symplast pathway
1. The movement of the ions through the extracellular pathway between the cell	1. The movement of minerals through the plasmodesmata of the cells is called

walls of the adjacent cells is called apoplast.	symplast pathway.
2. Ion easily reaches the endodermis cells by apoplast pathways. But the **casparian strips** of the endodermis prevent the further movement. Thus these ions must enter into the endodermal cells by diffusion or active transport.	2. There is a concentration gradient (higher to lower) down the cells of cortex, endodermis, pericycle and sap of xylem cell. So the minerals move down through plasmodesmata into the cells of cortex, endodermis, pericycle and then to the sap of the xylem.



Pathway of water movement in the root

MECHANISM OF ABSORPTION OF WATER

1. **Absorption of water by root hairs:** The absorption of water from the soil takes place through the root hairs. The root hairs are in contact with the water films on the soil particles. There is a thin lining of cytoplasm inside the root hair. This cytoplasm encloses a large vacuole filled with cell sap. The Cytoplasm and cell sap of the root hair are continuous with the root cell. The cell wall of the toot hair is a permeable membrane.

   The cell sap is aqueous solution of mineral salts and organic acid. Therefore, it exerts a high pressure. The soil solution is dilute. So it has a low osmotic pressure (less than I atm). The cell wall of the root hair contains pectic substances. So it imbibes soil water. Then this water passes into semi permeable cytoplasmic membrane by osmosis. Thus it removes film of capillary water from soil particle. It draws films of water from the adjacent soil particles. This process continues and water moves from considerable distances to the root hairs. This movement of water takes place due to cohesive forces between water molecules.

   The root hair cell absorbs water and becomes fully turgid. Therefore, its osmotic pressure fall and its turgor pressure increases. So the suction pressure of adjacent cortical cell increases. Thus it pushes water into cortical cells.

2. **Passage of water through endodermal cells:** Water passes from root hair cells to

the cortical cells. The endodermal cells have Casparian strips. They offer resistance in the flow of water. Therefore, water passes through endodermis by symplast pathway. Secondly, the endodermal cells opposite to the protoxylem do not have thickenings. These are known as **passage cells.** These cells allow the movement of water across the endodermis from the cortex to the protoxylem. Then water passes through pericycle and it finally reached at elements of the xylem.

3. **Reaching of water in the xylem:** The walls of the xylem vessels are inelastic. So it has no turgor pressure and the whole of the osmotic pressures of the xylem forms suction pressure. Therefore, it draws water from the pericycle cell. Thus gradient of suction pressure (diffusion pressure deficit) from the root hair to the xylem vessel helps in the absorption of water. The force with which water is drawn in from the soil depends upon the difference between the osmotic pressure of xylem sap and the soil solution.
4. **Root pressure:** Water is forced into the xylem vessels by the surrounding cortical cells with a certain force. This induces a pressure which raises the water to many feet in the xylem. This pressure is called root pressure. Root pressure is responsible for the phenomena of **bleeding** and **guttation.**

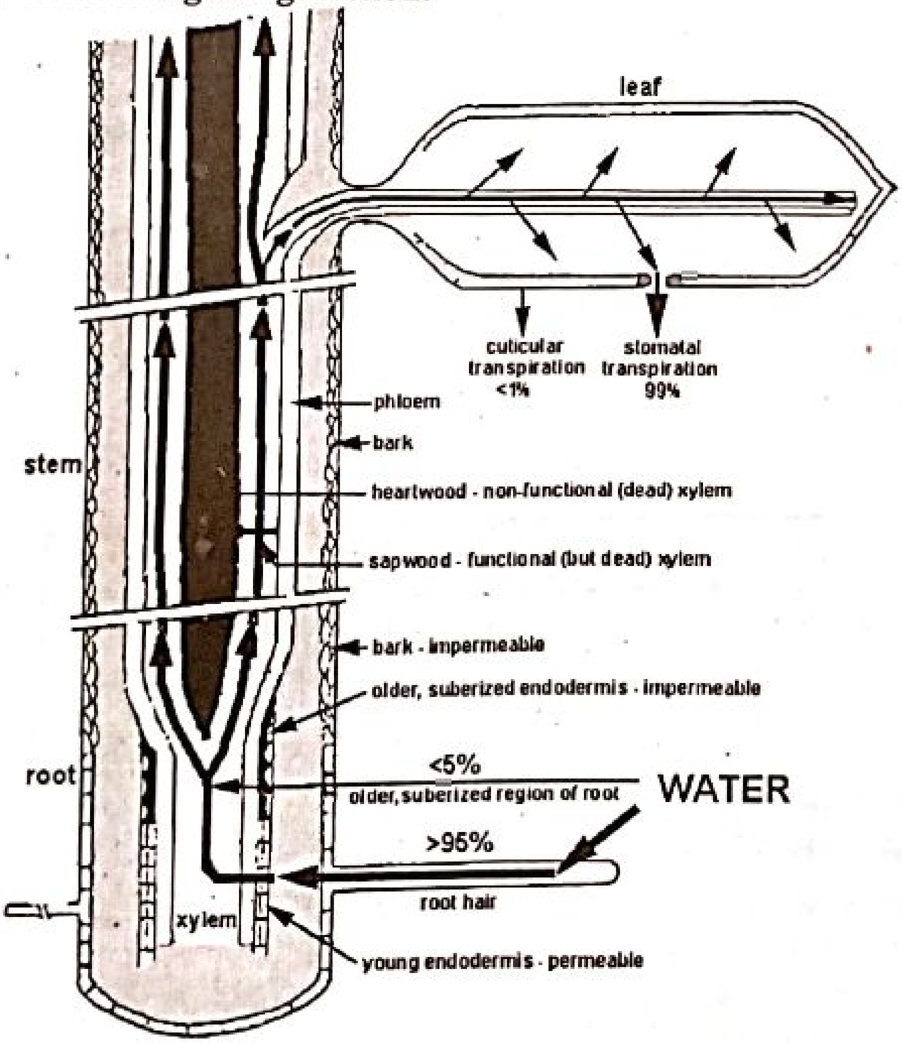

leaf
cuticular transpiration <1%
stomatal transpiration 99%
phloem
bark
stem
heartwood - non-functional (dead) xylem
sapwood - functional (but dead) xylem
bark - impermeable
older, suberized endodermis - impermeable
root
<5%
older, suberized region of root
WATER
>95%
root hair
xylem
young endodermis - permeable

Fig: Water absorption on plants

FACTORS AFFECTING ABSORPTION OF WATER

Following factors affect the absorption of water by root:

1. **Soil Temperature:** The rate of water absorption increases with a rise in soil temperature. But this rise to a limit. Temperatures above 35°C affect the permeability of the plasma membrane and decrease water absorption. Lowering of soil temperature greatly reduces water absorption. Cold soils are, therefore, physiologically dry. Some of the more important causes of decreased absorption at low soil temperatures are as follows:
    - Low temperature increases the viscosity of water.
    - Low temperature decreases the rate of root elongation.
    - Low temperature reduces the metabolic activity of the living cells of the roots.
2. **Soil air:** Water absorption also needs energy. This energy is released in the process of respiration. Oxygen is required for respiration. This oxygen is provided by soil air. Therefore, water absorption depends on availability of soil air. Waterlogged soils have little air. So the plants wilt in this soil.
3. **Soil water:** Increase in the water content of the soil increases water absorption. But this increase is to a certain limit. Over irrigation of soil decrease soil aeration. Thus it decreases the water absorption.
4. **Root system:** The absorption of water also depends on root system of plants. Some plants have well developed root system. It spreads ot large distances. Therefore, it increases the absorption of water.
5. **Association of mycorrhizae:** Mycorrhizae is an association of fungi and roots of higher plants. Fungi increase the ability of absorption of water by roots.
6. **Transpiration:** The rate of increase of transpiration increases the rate of absorption of water by the root. Transpiration produces transpiration pull in the xylems vessels. It pulls water upward. Thus negative pressure is produced in the xylem of root. It draws water from the soil.

TRANSLOCATION (ASCENT OF SAP)

The upward movement of water in a plant is called-the ascent of sap. A large quantity of water is absorbed by the roots. It must be conducted upwards to the transpiring surfaces against the downward pull of gravity. The distance covered is very large. It is sometimes exceeds 300 feet as in the eucalyptus and some conifers. All this upward movement requires some mechanism.

PATH OF WATER STREAM

The upward translocation of water in the plant takes place through the xylem. The water rises upward through the lumen of the xylem ducts. It does not rise through the walls of the xylem. The conducting vessels of the xylem form continuous capillary tubes. These tubes extend from the roots to the leaves through the stem. They communicate with each other through pits. These pits are present in their tapering end walls.

The vessels and tracheids of the outermost annual rings of the sapwood conduct water in the woody plants and trees. The heartwood plays no part. Therefore, the tree continues to live even after the heartwood decays and the trunk becomes hollow.

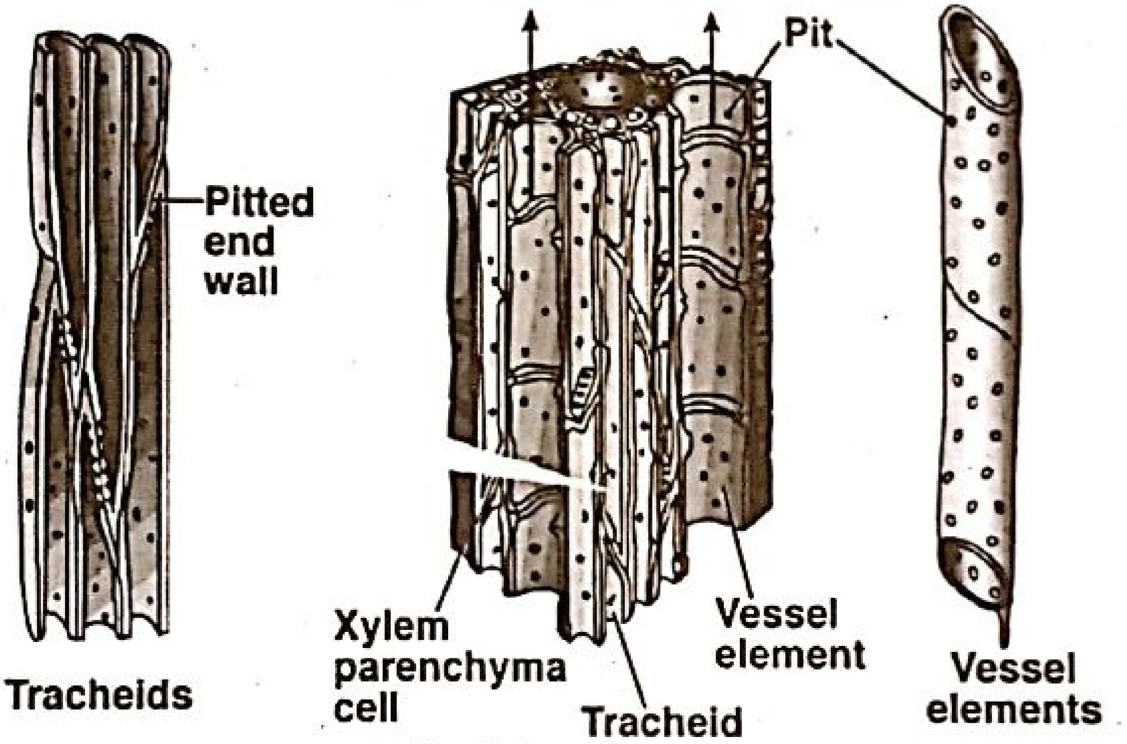


Fig: Xylem tissues

THEORIES OF ASCENT OF SAP

There are following theories which explain the ascent of sap in plants:
(a) Root pressure (b) Capillarity (c) Vital theory and (d) Cohesion-tension theory.

(a) ROOT PRESSURE

The hydrostatic pressure generated in the root which forces the water upward in the stem is called root pressure. Root pressure forces the water up from below. But it is believed that root pressure does not play much role in the ascent of sap due to following reasons:

1. The magnitude of root pressure is much lower. Thus this pressure is insufficient to raise water to much height. It rarely exceeds 3 atm. But a pressure of about 20 atm. is required to raise the sap to the tops of tall trees.
2. Root pressure shows seasonal fluctuations. New leaves are coming out and transpiration is slow in spring. So it is highest in spring. But transpiration is very rapid in summer. So it has lower value in summer. Therefore, it does not play any role in ascent of sap in summer.
3. Water continues to rise up in the absence of root pressure. Thus when a cut shoot is placed in water, it does not wilt
4. Root pressure has not been observed in gymnosperms.

(b) CAPILLARITY

A glass tube with a narrow bore is called a capillary tube. If one end of the capillary tube is dipped in water, the level of water rises in the tube. It occurs due to property of adhesion of water. Adhesion is the attraction of molecules of water with the glass. The phenomenon is called **capillarity.** The height of water in a capillary tube is inversely proportional to diameter of the bore. It means smaller the capillary bore, more water is raised. Xylem ducts acts as narrow capillary tubes. But capillarity does not play much role in the ascent of sap due to following reasons:

1. The capillary bore of xylem vessels and tracheids is about 40m in diameter. Its capillary force can raise water only up to 40 cm.
2. Capillarity works only if one of the open ends of the capillary tube is dipped in water. But this situation does not exist in nature. The xylem ducts of roots are not in contact with liquid water of the soil.

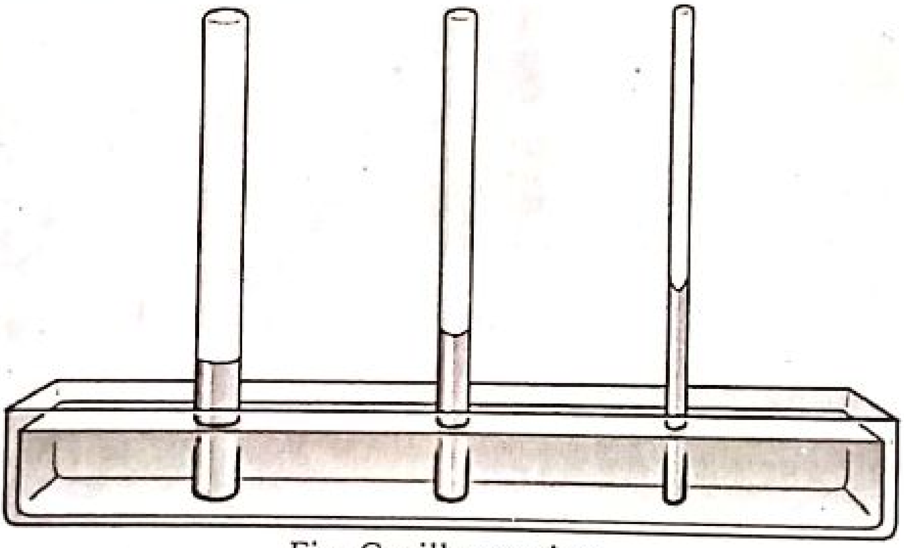


Fig: Capillary action

(c) VITAL THEORIES

There were two views about vital theory:

1. Vital theory was first proposed by **Godlewski**. According this theory the movement of water takes place due to the pumping activity of the cells of wood parenchyma and Medullary rays. The periodic change in their osmotic pressure causes pumping action. There is an increase of osmotic pressure in these cells. It withdraws water from the bordering vessels. Then their osmotic pressure is decreased. It pumps water into the above vessel. In this way water moved up step by step.
2. According to **J.C. Bose** (1923) the ascent of sap is due to the pulsatory activity of the cortical cells of the stem outside the endodermis.

Strasburgher disapproved this theory. He showed that water continued to rise in plants after death of their cells.

(d) COHESION TENSION THEORY

This theory was enunciated by **Dixon** (1910). This theory states that **the negative pressure or pull or suction is created in the leaves as a result of transpiration pulls the water upward.** According to this theory following factors play role in the ascent of sap.

1. **Transpiration pull:** Water is evaporated from the stomata by transpiration. It produces negative pressure or suction pressure in the leaf. This pressure pulls the water upward.

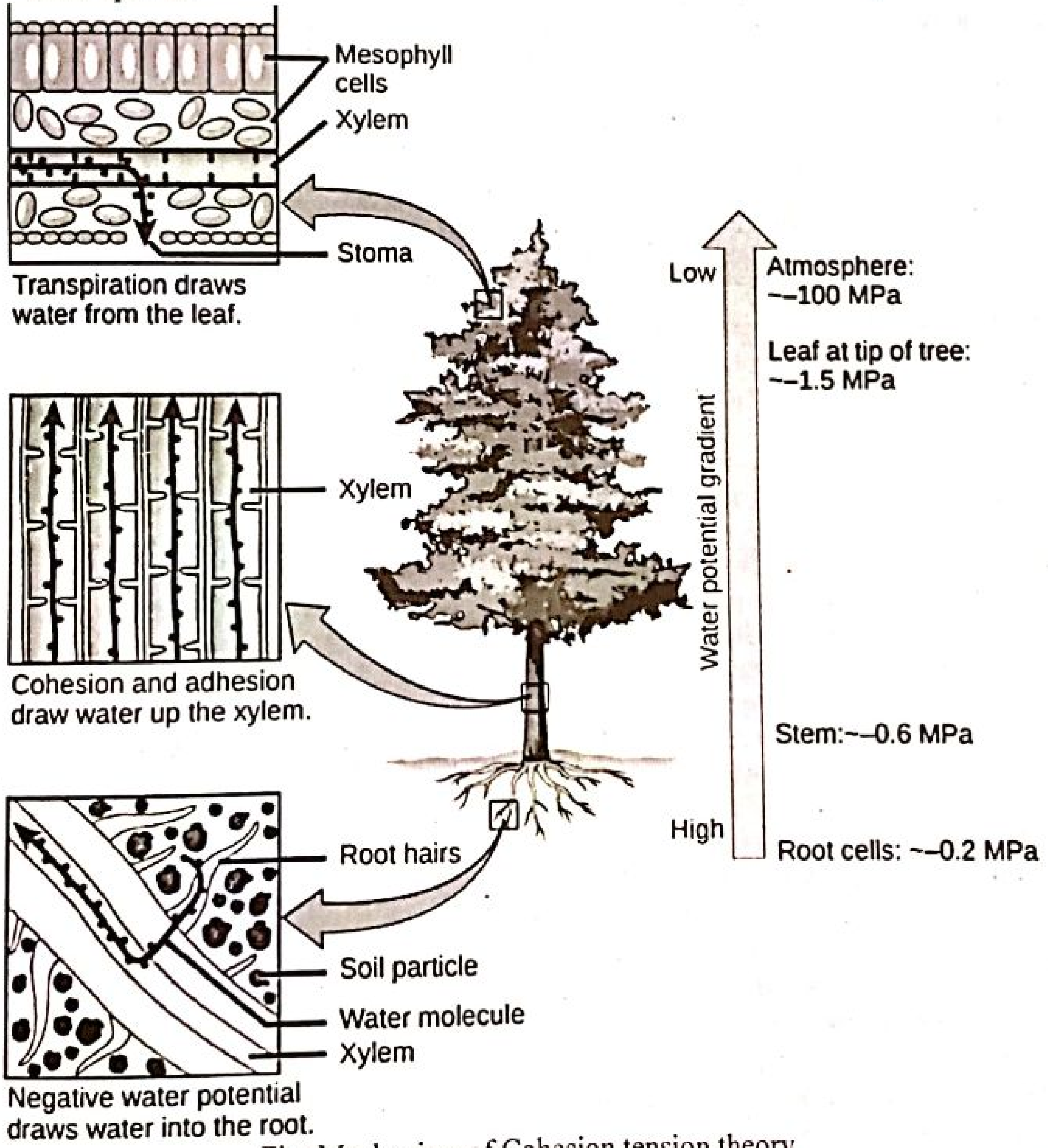

Mesophyll cells
Xylem
Stoma
Transpiration draws water from the leaf.
Xylem
Cohesion and adhesion draw water up the xylem.
Root hairs
Soil particle
Water molecule
Xylem
Negative water potential draws water into the root.
Low
High
Water potential gradient
Atmosphere: ~–100 MPa
Leaf at tip of tree: ~–1.5 MPa
Stem: ~–0.6 MPa
Root cells: ~–0.2 MPa

Fig: Mechanism of Cohesion tension theory

2. **Cohesion:** The force of attraction among the water molecules is called cohesion. The cohesion holds water together. It forms a solid chain like column within the xylem tubes. There is hydrogen bonding between the molecules of water.

3. **Tension:** The pulling of water upward produces tension in the xylem tubes. The transpiration provides the necessary energy or force. The hydrogen bonds between the water molecules produce this tension. The xylem water tension is much stronger. It can pull the water up to 200 meters (more than 600 feet) in plants.
4. **Adhesion:** The attraction between the water molecules and the cell wall of the xylem cells is called adhesion. The water molecules remains adhere to the xylem tissues. So the column of water in the xylem tissues does not break. The composition of the cell wall provides this necessary adhesion for the water molecules. It helps the water molecules to creep up. The cellulose of the cell wall has special affinity with water. Cellulose can imbibe water.
5. **Strong xylem wall:** The xylem walls have high tensile strength. So they do not buckle inwards. The lignin and cellulose provide strength to the cell wall of the xylem tissues.

Mechanism of transpiration pull

1. **Mesophyll cells:** Water evaporates from the intercellular spaces of the leaves into the air. It withdraws water from the mesophyll cells. The water vapours pass out through the stomata. More water evaporates from the saturated walls of the mesophyll cells. The cell walls withdraw water from the vacuoles of cells. Hence the osmotic pressure of mesophyll cells is increased, and their turgor pressure falls. It increases their suction pressure. Therefore, these cells withdraw water from the deeper mesophyll cell. In this way a gradient of suction pressure is established.
2. **Xylems:** This suction pressure reaches the parenchymatous cells. These cells draw out water from the xylem vessels. The greater the water loss by transpiration the greater will be the magnitude of the force. This force then pulls up the water in the xylem vessels of the stem from above.
3. **Root:** Transpiration pull produces tension in the xylem. This tension is transmitted down the column of water in the xylem elements through the stem. It reaches the absorbing region of the root. As a result the whole column of water is lifted up.
4. **Water column:** Cohesive forces are present between the water molecules. These forces maintain the continuity of water column in the xylem. The magnitudes of this cohesive force are very large. It may be 350 atm. This means that a force greater than 350 atm. is required to break a column of water. These enormous cohesive holds water molecules together like a cord or wire. The rising column of water is called **transpiration stream.**

Objections

Cohesion- tension theory is the most accepted theory. But there are a few objections to cohesion-tension theory.

1. The water column in a glass tube would break on shaking. The plants are bent severely in a strong wind. It can break the column of water. This does not happen. The xylem ducts have very narrow bore. Therefore, there is greater adhesion between water and the xylem walls. It does not allow the water column to break.

2. Dissolved gases may appear and form babbles inside the xylem ducts due to change in temperature. These bubbles can break the continuity of water column in the xylem. But there is high tension in the xylem. This tension dissolves any air bubble.

TRANSPIRATION IN PLANTS

The evaporation of water from the aerial part of plant is called transpiration. Transpiration is not a purely physical process like evaporation. It is a vital phenomenon. It plays important role in the cell. The amount of water lost by transpiration is very large. It exceeds the final dry weight of the plant by several hundred times. A corn plant during its life of a few weeks transpires a large amount of water. This water can fill a barrel. Similarly, medium sized tree may lose more than a ton of water every day. It has also been estimated that every ounce of dry matter in the aerial parts of a crop plant loses 20—50 pounds of water by transpiration.

Demonstration of transpiration

A potted plant is placed under a bell jar. The soil in the pot is watered and the pot is covered with rubber sheet or the soil. The walls of the pot are coated with paraffin. After a short time, drops of water will appear on the inner surface of the bell jar. This water has come from the aerial parts of the plant.

TYPES OF TRANSPIRATION

There are two type of transpiration: foliar transpiration and lenticular transpiration.

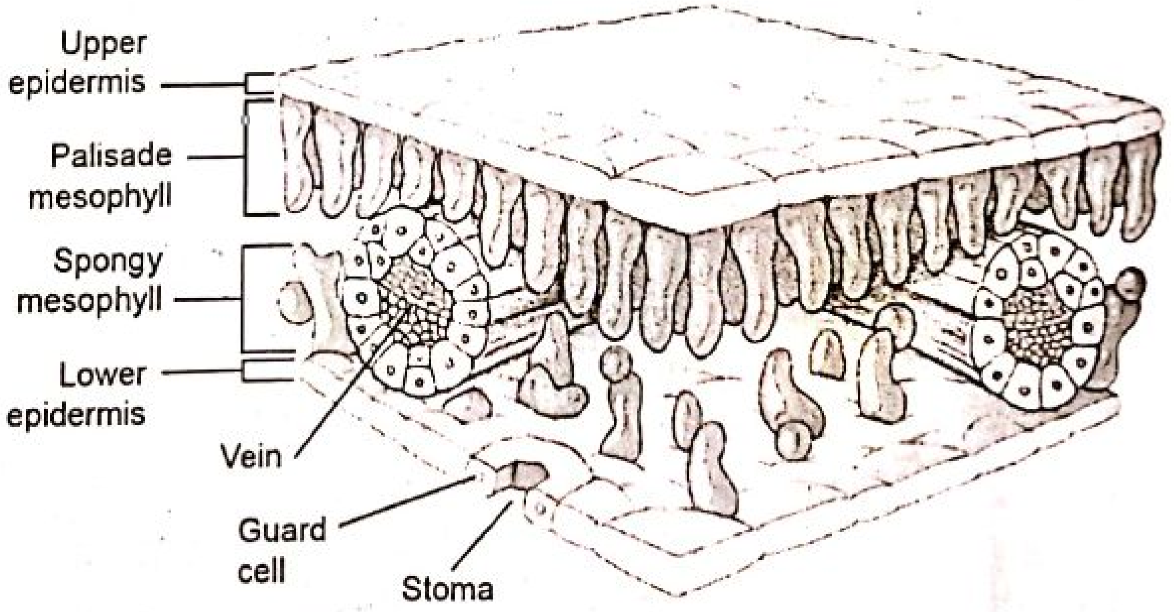


Fig: Section of leaf

1. Foliar transpiration

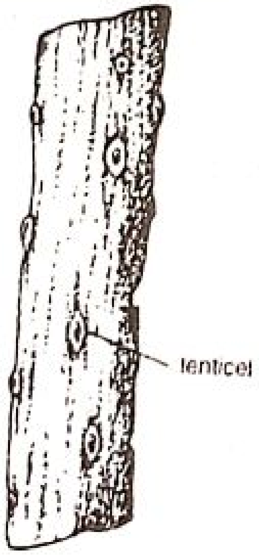
The transpiration which takes place through the leaves is called foliar transpiration. The foliar transpiration may be stomatal transpiration or cuticular transpiration.

(a) Stomatal transpiration: The transpiration which takes place through the stomata is called stomatal transpiration. The lower part of leaf has the loosely packed spongy mesophyll cells. They have a number of large intercellular spaces. These air spaces communicate with the outside atmosphere by means of stomata in the leaf epidermis. The xylem of the leaf vein supply water to the cells of the mesophyll by osmotic diffusion. Mesophyll cells become turgid and saturated with water. Water evaporates from their moist walls into the internal atmosphere of the intercellular spaces of the mesophyll. It becomes saturated with water vapour. Finally water vapours move out of stomata. The leaves are divided into two groups on the basis of stomata:

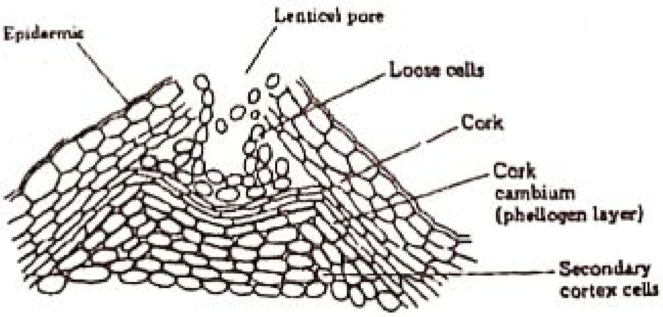
- **Isobilateral leaves:** In these leaves, the stomata are present in both upper and lower epidermis. E.g. lily and maize (corn) leaves.
- **Dorsiventral leaves:** In these leaves, the stomata are present only in the lower epidermis.

(b) Cuticular transpiration: The transpiration which takes place though the cuticle of the leaf is called cuticular transpiration. Cuticle is present on outer walls of the epidermal cells. The cuticle is not permeable for water. Therefore, the amount of water lost through it is small. It is only 3 to 10% of the total transpiration. Cuticle transpiration depends upon the thickness of the cuticle. The cuticle is poorly or not at all developed in herbaceous plants growing in humid and shady places. Therefore, their cuticular transpiration becomes equals to the stomatal transpiration. Transpiration from stems, fruits and flower parts is mostly cuticular.

The stomata are almost closed at night. Therefore, Cuticular transpiration takes place at night. The general factors affecting the rate of transpiration also affect the rate of cuticular transpiration.



(A) Lenticels on bark of tree



(B) Structure of lenticel

2. Lenticular transpiration

The loss of water vapours through the lenticels is called lenticular transpiration. Lenticels are aerating pores in the bark of some plants. All plants do not possess lenticels. Lenticular is about 1 – 2 % of the total respiration.

The lenticels are also involved in the exchange of gases like stomata with the environment. Water is lost from the lenticels in the form of water vapours (transpiration). The strong light and temperature increase the rate of diffusion. So the loss of vapours from lenticels also increases in the strong light and high temperature.

The lenticels appear in the form scars or small protrusions on the surface of stem. The cork cambium forms oval, spherical or irregular cells at lenticels of the cork. Lenticels consist of loose mass of small, thin-walled cells. These masses are loosely arranged. They have a lot of intercellular spaces.

FACTORS AFFECT THE RATE OF TRANSPIRATION

Following factors affect the rate of transpiration:

(a) External factors

1. Humidity of air

Water is evaporated through the stomata. This follows the simple law of diffusion. This diffusion can take place only if the water vapour content of the outer atmosphere is less than that of the intercellular spaces of the leaf. Transpiration is negligible in an atmosphere saturated with water. The drier the air, the more rapid is the transpiration. Following factors affect the humidity of air:

a) **Saturation deficit:** Saturation deficit is the difference between the amount of water vapour actually present in the air and the amount necessary to completely saturate it. The rate of transpiration depends upon the saturation deficit.

b) **Absolute humidity:** The amount of moisture actually present in the air is called its absolute humidity

c) **Relative humidity:** The percentage of the amount of moisture necessary for saturation at a particular temperature is called relative humidity. The relative humidity decreases (or increases) with every rise in the temperature. But the absolute humidity remains unaffected. The rate of transpiration increases at lower relative humidity of the air and vice versa.

2. Temperature

Temperature affects the saturation deficit of the air. So it has an indirect influence on the rate of transpiration. Rise in temperature decrease the relative humidity of the air. It increases the rate of transpiration. Low temperatures decrease the capacity of the air to hold moisture. Therefore, it increases the relative humidity. It decreases the rate of transpiration. High temperatures also open the stomata widely. It increases the transpiration.

3. Wind

The moving air is called wind. Wind has a powerful effect on humidity. Dry wind removes the moist air from the immediate vicinity of the plants. It lowers the amount of air moisture near plant. As a result, the humidity of the air is lowered. It promotes transpiration.

4. Light

Rate of transpiration increases in light and decreases in the darkness. Light affects transpiration in two ways. It raises the temperature of the leaves and increases the transpiration. Secondly, stomata are opened in the presence of light. It increases transpiration.

5. Atmospheric pressure

Low air pressure reduces the density of the air. Thus it increases the rate of transpiration. Air pressure is lowered at high altitudes.

6. Availability of Soil Water

There should be enough water absorbed by the roots from the soil. It will compensate the water lost by transpiration. When there is lower absorption of water, there will be low rate of transpiration. The factors which affect the absorption of water also affect the rate of transpiration.

(b) Internal factors

1. **Role of stomata:** Most of the transpiration takes place through stomata. Transpiration depends on the opening and closing of stomata. Different factor affect the opening and closing of stomata.
2. **Water relation of the Parenchyma cell:** The parenchyma mesophyll cells also control the rate of transpiration. They become saturated with water. Thus their walls easily lose water into the internal atmosphere of the leaf. This loss of water is compensated by absorption of water from the root. If root cells do not absorb much water then the water content of the mesophyll cells decreases. Therefore, mesophyll cells loss turgor. Their cell walls become dry. Thus the evaporation from their surfaces is reduced although the stomata remain open. As a result osmotic pressure of the mesophyll cells increases. Thus they withdraw water from the guard cells. The guard cells lose their turgor. Thus stomata are closed even in the presence of light. Thus the internal water relation of the leaf are self regulating mechanism for the control of transpiration
3. **Carbon dioxide concentration:** Sometimes, the photosynthesis exceeds respiration. So there is low concentration of carbon dioxide in the leaves during these days. It stimulates the active transport of potassium ions into the guard cells. The potassium ions open the stomata. Thus CO_2 is diffused into the mesophyll cells of the leaves. Cellular respiration takes place at night in the absence of photosynthesis. So the CO_2 level is raised in the leaves. It stops the inward transport of K^+. Thus water is removed from the guard cells and they become flaccid. So stomata are closed. It stops the transpiration.
4. **Number of stomata per unit area:** The number of stomata per unit area of leaf surface and their position also affect the rate of transpiration. The stomata are sunken in depression below the epidermis in some plants like oleander and Pinus. It reduces the rate of transpiration.
5. **Thickness of cuticle:** Cuticular transpiration depends upon the thickness of cuticle. If

cuticle is thin, there is more transpiration and vice versa.

TRANSPIRATION AS A NECESSARY EVIL (IMPORTANCE OF TRANSPIRATION)

The transpiration is inevitable. So it is taken as necessary evil. But the transpiration is harmful. The cells have wet surfaces. So evaporation of water occurs from these cells. There can be serious desiccation in plant. Thus the plant can wilt due to loss of this water. The condition of drought often causes the death of the plant. Even mild water stress can reduce the growth rate of the plant. It may cause economic losses due to reduction of yield.

Despite these harmful effects, the transpiration has great importance for the plants.

1. Water is transported in most tall plants with the help of transpiration pull.
2. The mineral are dissolved in the water. The transpiration stream distributes these minerals throughout the plant body.
3. The exposed surfaces of the cells of the leaves are cooled due to evaporation of water.
4. Transpiration keeps the leaf wet. So the gases are exchanged through the wet surface of the leaves.

Role of transpiration

Transpiration has great effects in plant life. It gives great benefit to the plant. It also has some harmful effects.

Beneficial roles of transpiration

1. Gaseous exchange

Transpiration is essential in the life of land plants. It helps in the absorption of carbon dioxide (CO_2) from the atmosphere during photosynthesis. Openings of stomata in day time help in gaseous exchange.

2. Cooling effect

The leaves absorb the radiant energy. Some of the light energy is used in photosynthesis. The rest is converted into heat energy. It increases leaf temperature. However, there is rapid loss of water in the form of water vapour. It occurs from the aerial parts of the plant through transpiration. It brings down their temperature. Transpiration thus provides a significant cooling effect. It keeps the plant from being over heated.

3. Effect on mineral transport

Mineral salts remain dissolved in the soil water. Thus these are absorbed by the roots. Minerals are absorbed and accumulated in the xylem duct of the root. They move up and are distributed in the plant by the transpiration stream.

4. Effect on water movement

The absorbed water is transported from roots to leaves through the xylem vessels. It occurs by transpiration pull. There is water loss due to transpiration. It results in the development of low water potential in the leaf tissues. Thus water moves from the xylem vessels to the leaf cells. Thus transpiration helps in the ascent of sap.

5. Development of mechanical tissues

Greater amount of transpiration helps in development of mechanical tissues in plants. The plants become healthier and more compact. The cell walls become thick and cutinized. Thus plants are able to resist attack of fun and bacteria.

6. Maintenance of turgidity

Transpiration maintains an optimum degree of turgor in cells. Under favourable conditions plants absorb excess amount of water. It is given off by transpiration to maintain the optimum turgor for better growth.

7. Increase of taste of fruits:

The solutes inside the cell become more concentrated due to transpiration. It causes accumulation of sugar solution in the cells of fruits increases. Thus fruits taste sweeter.

Harmful effects of transpiration

Curtis has said transpiration is a necessary evil due to following facts:

1. A large amount of absorbed water is lost during transpiration. It is harmful to plants.
2. Unnecessary wastage of energy takes place during process of water absorption. It is lost due to transpiration.
3. Sometimes, rate of transpiration is high in plants growing in soil deficient in water. Here an internal water deficit develops in plants. This may affect metabolic process.
4. Many xerophytes plants undergo structural modifications and adaptations. These are for checking transpiration.

Conclusion

We have considered both the beneficial and harmful effects of transpiration. We can conclude that transpiration is definitely advantageous in spite of its harmful features.

STOMATA AND ITS PHYSIOLOGY

STRUCTURE OF STOMATA

The stomata are the pathways through which transpiration and gaseous exchange take place. The stomata are elliptical pores in the epidermis of plants. They occur mostly on the under surface of leaves.

1. Guard cells

A stoma is bordered by two **guard cells**. The guard cells are specialized epidermal cells. The guard cells are smaller in size than the other epidermal cells. They are kidney shaped in surface view. But they are elongate in gamily Gramineae. In some species of grasses, the epidermal cells adjacent to the guard cells are different in shape and size from the other the epidermal cells. These are known as **subsidiarsy cells or accessory cells.** Guard cells have some specific features.

(i) The guard cells are modified epidermal cells. But they are different shape, contents and metabolism. They contain mitochondria, peroxisomes and endoplasmic reticulum.

(ii) They also contain chloroplast. Chloroplasts are absent in all other epidermal cells.

(iii) The starch grains present in guard cells decrease during the day time. But increase during night. On the other hand starch accumulates during the day and consumed during the night in the other epiderrnal cells of the leaf.

(iv) The inner wall of the guard cells surrounding the pore is thick. But it outer wall is thin.

2. Size and number of stomata

The size of the stomatal aperture varies from 7 x 3μ to 38 x 8μ. But these variations occur in different species. Sometimes, their size is different in the different leaves of the same plant and in the same leaf at different points.

The number of stomata varies from 50 and 300 per square mm. But their total area does not exceed 1 to 2% of the entire surface.

3. Position and distribution of stomata

There are different categories of plants for position of stomata.

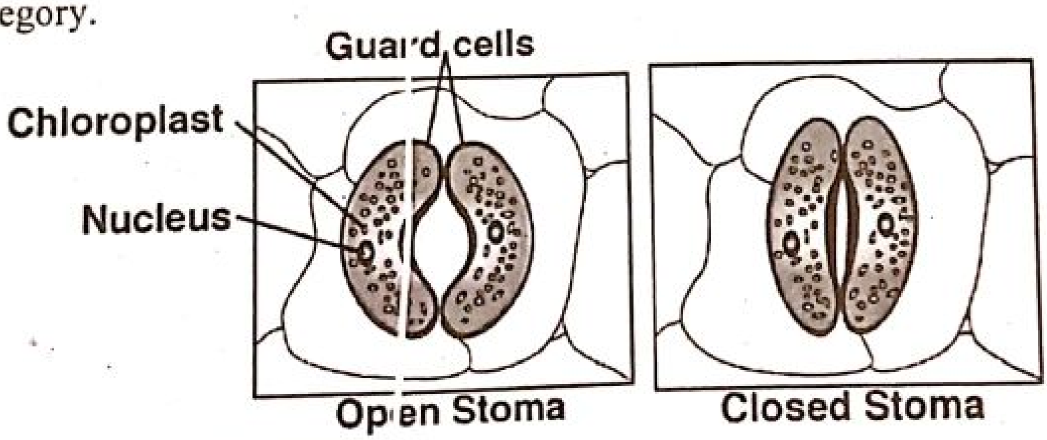
(i) Apple and Mulberry Types: These have stomata only on the under surface of the leaf. Its examples are peach walnut oak, apple and mulberry.

(ii) Potato Type: In this case, the stomata are more numerous on the underside than on the upper surface of the leaf. Its example is cabbage, bean, pea and tomato.

(iii) Oat Type: Stomata are more or less equally distributed on the two surfaces. Most of the cereals like wheat and maize belong to this category.

(iv) Water Lily Type: These have stomata only on the upper surface of leaf. Aquatic plants with floating leaves belong to this category,

(v) Potamogeton Type: In this case stomata are altogether absent. If they are present, they are functionless and vestigial. Most of the submerged aquatic plants belong to this category.



STOMATAL PHYSIOLOGY

(Mechanism of opening and closing of stomata)

Role of turgor of guard cells

Guard cells play an important role in the opening and closing of stomata. The change of osmotic concentration and shape of guard cells controls the opening and closing of stomata. The inner wall of guard cells is thick and inelastic. It resists stretching. But their outer wall is thin and elastic. So it can be stretched. The differences between the inner and outer walls of the guard cells are responsible for opening and closing of the stomata.

(a) Gain of turgor: The guard cells absorb and water become turgid. The outer thin walls are stretched. But the inner thick wall is inelastic. So it fails to stretch and is pulled apart. It becomes concave. It increases the gap between the guard cells. The stomata is now open.

(b) Loss of turgor: The guard cells loss water. So they loss of turgor. Therefore, the inner walls of the guard cells become straight. The walls of both guard cells come close to each other and the stomatal pore becomes narrow and finally closes.

THEORIES OF OPENING AND CLOSING OF STOMATA

Following theories explains the change of osmotic concentration in the guard cells.

(a) STARCH-SUGAR HYPOTHESIS

This hypothesis was formulated by **S.D. Sayre** in 1926. According to this hypothesis, one of the important enzymes present in the guard cells is starch phosphorylase. It is reversible enzyme. Its action is controlled by pH of cells.

(i) **High pH:** Light falls on leaf. So carbonic acid is broken into CO_2. Thus the pH of the guard cells increases. This increase in pH stimulates the enzyme to converts starch into glucose-1-phosphate in the presence of inorganic phosphate. Starch is insoluble and osmotically inactive. But glucose phosphate is soluble. So it increases the osmotic pressure of guard cells. As a result, water from adjacent epidermal cells enters the guard cells. The guard cells become turgid and are opened.

(ii) **Low pH:** Carbon dioxide accumulates in the dark. It reacts with water to from carbonic acid (H_2CO_3). Therefore, pH decreases. Therefore, the reaction becomes reversed. Now same enzyme converts glucose-I-phosphate into starch. Starch is insoluble in water. Therefore, the osmotic pressure of guard cells decreases. As a result the guard cells lose water and become flaccid. It closes the stomata.

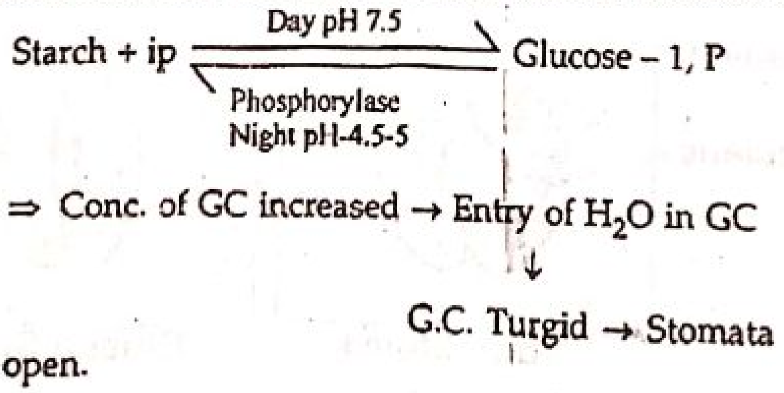


Fig: Starch- sugar hypothesis

Evidences in support of hypothesis:

1. Some plants were exposed to vapours of ammonium hydroxide in the dark. It increases the pH. Therefore, the stomata were opened in darkness.
2. Similarly, some plants are exposed to glacial acetic acid at day time. Their pH decreases .So their stomata are closed during the day time.
3. Some wavelengths of light, blue and the red affect the stomatal opening and

photosynthesis. Therefore, the action spectrum for stomatal opening and photosynthesis is same.

4. The phosphorylase is very active enzyme. It converts starch into sugar and sugar into starch rapidly. It is estimated that one enzyme can convert 1000 molecules of starch per second into sugar. This speed is enough to open and close stomata rapidly.

Objections

1. Starch is absent in some plants like onion. But still their stomata open and close.
2. Stomata can open in very dim sunlight or even in moonlight. Photosynthesis cannot take place at this intensity.
3. Steward (1964) pointed out that inorganic phosphate itself is osmotically active. Therefore, the conversion of starch to glucose phosphate does not affect osmotic pressure of guard cells.

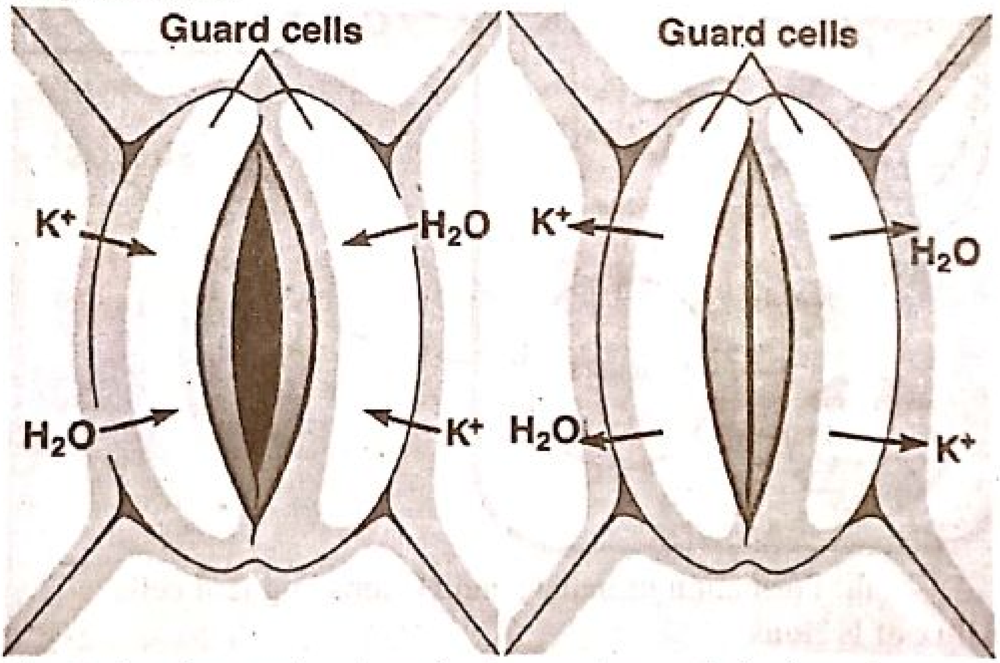


Fig: Role of potassium ions in the opening and closing of stomata

(b) POTASSIUM (K^+) ION EXCHANGE HYPOTHESIS

It is also called **malate hypothesis.** This hypothesis gives following mechanism of opening and closing of stomata:

(i) **Opening of stomata:** Malic acid is produced in the guard cells in the presence of light. It is believed that malic acid is produced in the chloroplasts. Then it is excreted into the cytoplasm of the guard cells. Malic acid is a weak acid. Therefore, it dissociates into malate ions and hydrogen (H^+) ions. Hydrogen ions are excreted from the guard cells and potassium ions (K^+) enter the guard cells from neighbouring cells. Thus exchange of hydrogen and potassium ions between guard cells and adjacent epidermal cells takes place. This ion exchange is an active process. It needs expenditure of metabolic energy. Accumulation of potassium and malate ions in guard cells increase in the osmotic pressure of guard cells. Therefore, water flow into guard cells. The guard cells become turgid and are opened.

(ii) Closing of stomata: Potassium and hydrogen exchange pump again work at dark. Hydrogen ions enter and potassium ions leave the guard cells. Malate and hydrogen ions recombine to form malic acid. It is used in respiration. It reduces the osmotic pressure of guard cells. Thus the guard cells loss turgidity and stomata are closed. Potassium ion exchange mechanism is found in all the plants.

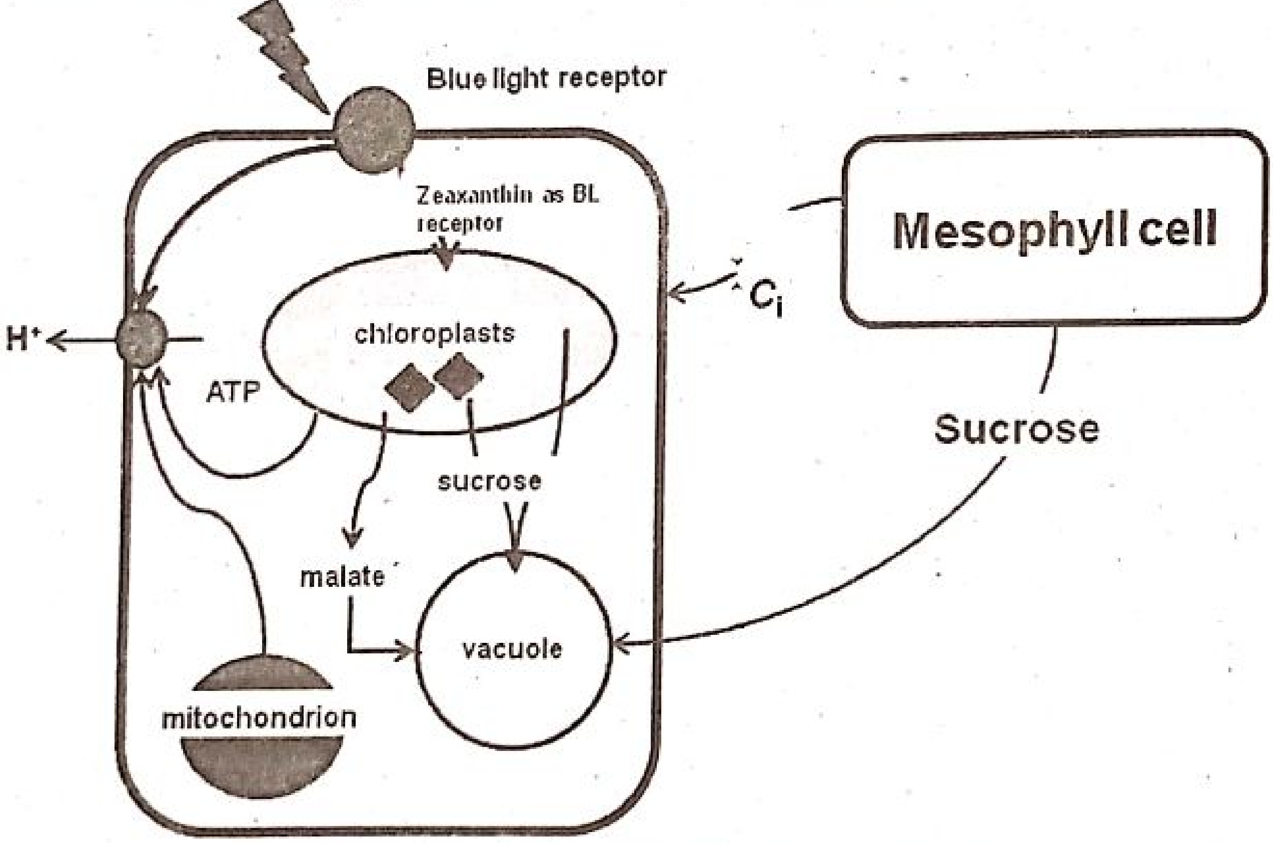


Fig: Formation of malate and H^+ ions in guard cells

Control of influx of K^+ ions

The level of CO_2 in the space inside the leaf and light control the movement of K^+ ions into and out of the guard cell.

1. **Carbon dioxide:** A low level of the CO_2 increases the movement of K^+ ion the guard cells. So the stomata are opened and CO_2 enters into the leaf. Thus it increases the rate of photosynthesis in light.
2. **Blue light:** The blue light makes the medium of the guard cells acidic. The guard cells pump out the protons (H^+). It enables the guard cells to take up k^+ ions. So the guard cells absorb water and become turgid. Thus they open the stoma.
3. **Role of hormones:** Some hormones are involved in the movement of stomata. The mesophyll cells release a hormone at high temperature. This hormone is called **abscisic acid**. This hormone stops the active transport of K^+ into the guard cells. It closes the stomata.

Latest research

Latest research has revealed that the level of CO_2 in the guard cells and blue light affect the potassium ion exchange. Low level of CO_2 and blue light enable the guard to take in

K^+ ion. So stomata are opened. But high level of CO_2 and absence of blue light reverse the affect and stomata are closed.

TRANSLOCATION OF ORGANIC SOLUTES (Out of Syllabus)

Only for University of Baluchistan and Islamia University of Bahawalpur (IUP)

Phloem transport

The Organic solutes are transported by phloem tissue. The phloem is present on the outer side of the vascular tissues. It is present in both primary and secondary vascular tissues. The phloem forms the **inner bark**. The phloem tissues are involved in the conducting and transport of sugars and other organic material. The phloem tissues are composed of following cells:

1. **Sieve elements:** These are directly involved in the transport of organic solutes.
2. **Companion cells**
3. **Parenchyma cells**
4. **Fibers, sclereid and latex containing cells.** These structures are present only in some phloem.

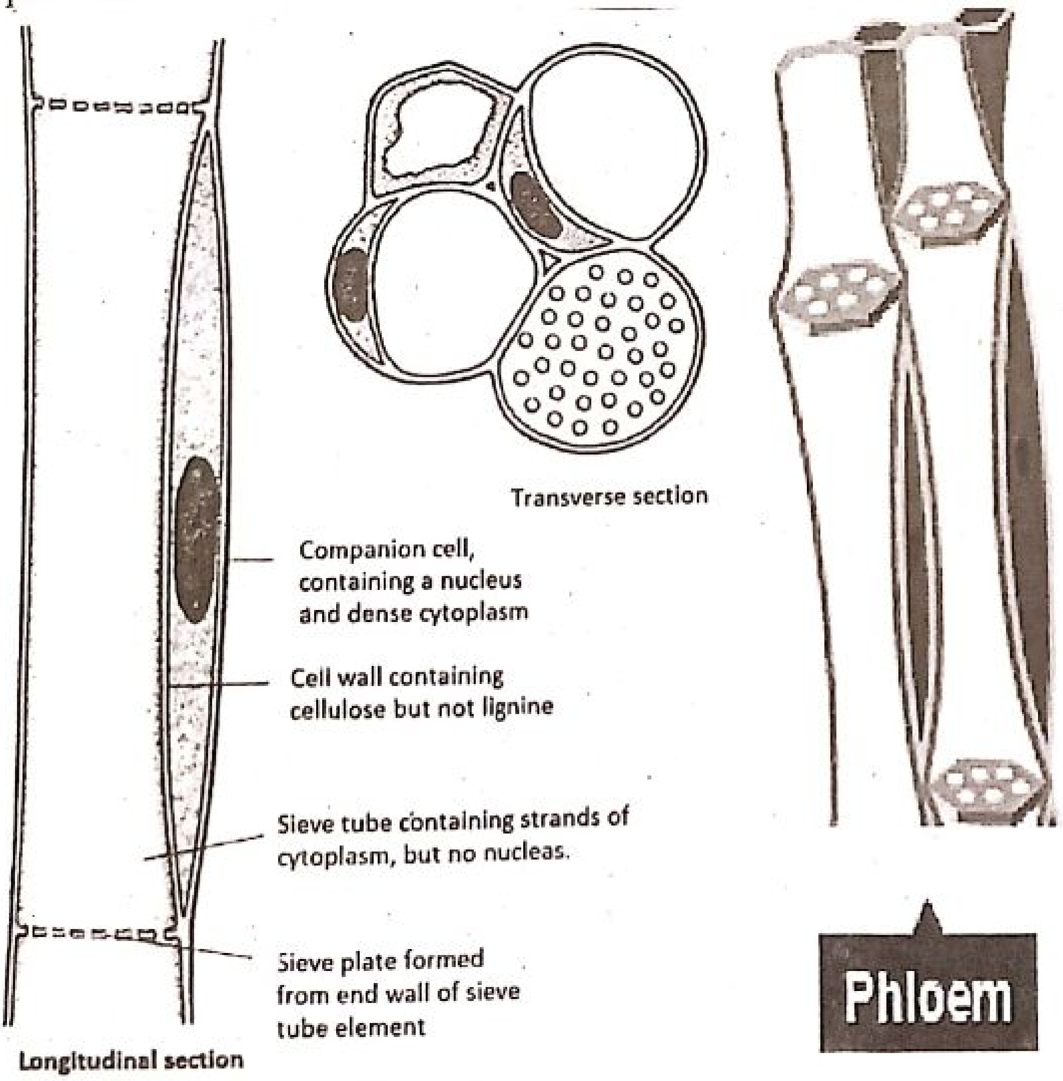

Transverse section
Companion cell, containing a nucleus and dense cytoplasm
Cell wall containing cellulose but not lignine
Sieve tube containing strands of cytoplasm, but no nucleas.
Sieve plate formed from end wall of sieve tube element
Longitudinal section
Phloem

Fig: Phloem components

1. Sieve elements or sieve tube members

The sieve elements are characterized by **sieve areas. The portions of the cell wall which interconnect the conducting cells are called sieve areas.** The sieve areas are generally formed at the end walls of the sieve tube members. The individual sieve tube member cells are joined by these end walls. **The sieve tube members are joined longitudinally in a series to form sieve tube.** There are pores in the sieve plates. So sieve tubes are open channels and transport of material takes place between the sieve elements.

2. Companion cells

One or more companion cell is associated with each sieve tube member. The sieve tubes and companion cells are communicated with each other by **plasmodesmata**. Companion cells provide ATP and proteins to sieve tubes. The photosynthetic products pass from the photosynthesizing cells (mesophyll and palisade cell of leaf) into the sieve tube through companion cells.

Composition of phloem material

The composition of phloem material was studied by using aphids. **Aphids** are phloem feeder insects. Aphids insert their **stylets** into stem or leaf and puncture the sieve tube. There is pressure of sieve tube cell. This pressure forces the sap into the aphid's digestive tract. The sap comes out of the posterior end of the aphids as **honey dew**. The honey dew or phloem material has 10 – 25% dry matte. 90% of this dry matter is sucrose. Nitrogenous compounds are 1% of the dry matter.

PATTERN OF TRANSPORT

The transport or translocation occurs from the area of supply (source) to the area of metabolism or storage (sink). The movement in phloem takes place from source to sink in most of the plants during active photosynthesis. The phloem transport does not occur only in an upward or a downward direction. It has no link with the gravity.

1. Areas of source

The exporting organs like a mature leaf or storage organ are called areas of source. These may be storage organs or sink. There are following storing organs:

a) Storing of photosynthetic products. These products are in excess of the need of plants.

b) Storage organs during the exporting phase of its development. It takes place in biennial plants. For example root of beet is a sink in first growing season. But it becomes source in the next season. The beat utilized this food in the growth of new shoots.

2. Sinks

The areas of active metabolism or storage like roots, tubers, developing fruits and immature leaves are called sink. They may be even growing tips of the stem and roots.

Mechanism of Phloem Translocation or Transport

There are two types of theories which explain the mechanism of transport in phloem. These are:

1. Active theories

These theories involve active transport for the movement of material in phloem. Active transport uses energy. No evidences are available to support these theories. So these theories have been abandoned.

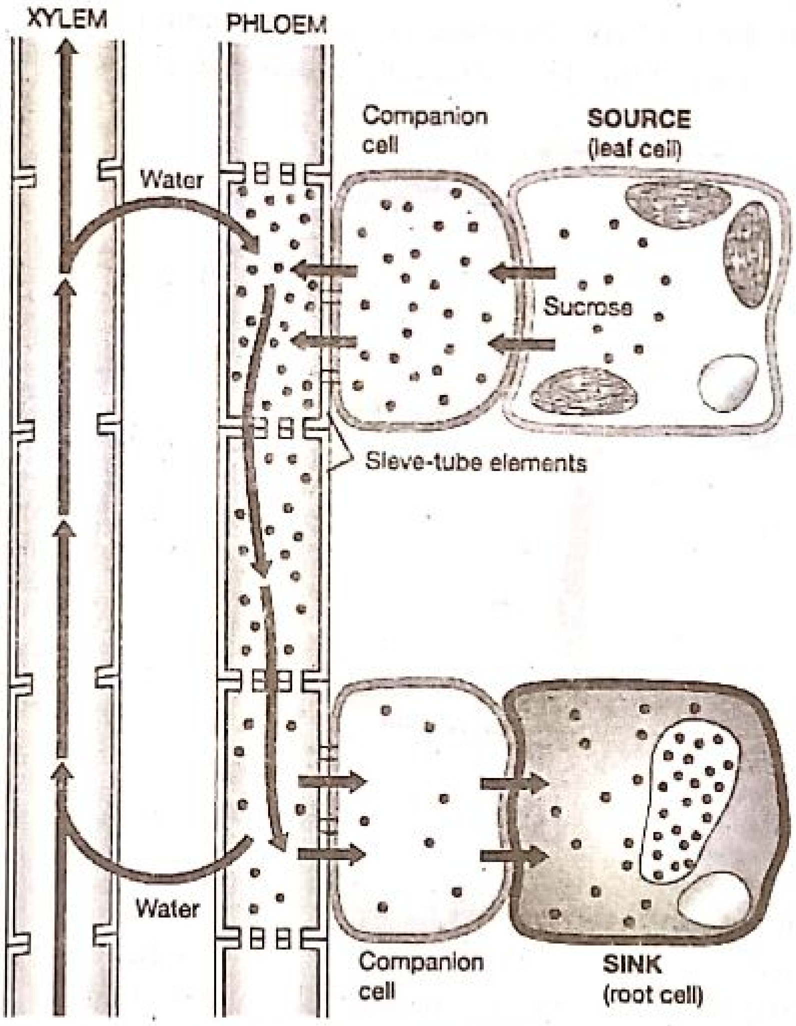


Fig: The pressure flow theory

2. Passive theories

These theories do not involve the use of energy. Evidences are available to support these theories. So these theories are accepted. There are two types of passive theories. These are:

(a) Diffusion

The movement of molecules from the higher concentration to the lower concentration is called diffusion. Diffusion is a very slow process. It cannot explain the high speed of sugar movement in the phloem. The average speed of the sugar movement in the phloem is 1 meter per hour. But the rate of diffusion is 1 meter per eight years. So diffusion cannot transport the material through the phloem.

(b) Pressure Flow Theory

The pressure flow theory gives the mechanism of the translocation in phloem of angiosperm. It is the most acceptable theory. A hypothesis was first proposed by **Ernst Munch** in 1930. It states that: **an osmotically generated pressure gradient between source and sink drives the solution through the sieve elements.** Now this hypothesis has been give the status of theory. There are following steps in the pressure flow theory.

1. Formation of sucrose

Glucose is formed in the photosynthesizing cells. Some amount of the glucose is used within the cell during respiration. The remaining glucose is converted into non-reducing sugar i.e. **sucrose.**

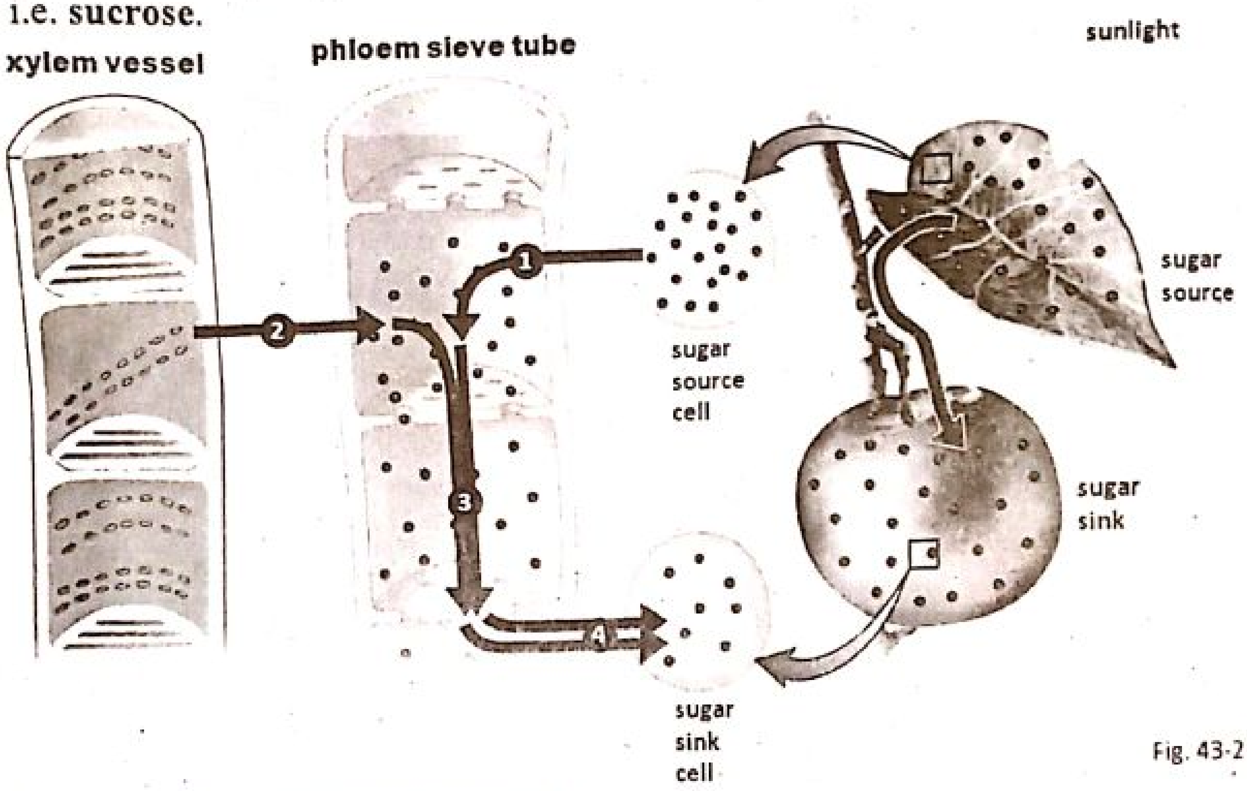


Fig. 43-2

2. Transport of sucrose into sieve tubes

This sucrose is passed through the bundle sheath cells (around vascular bundle in leaf)) and it is actively transported into the companion cells of the smallest vein. This vein has short transport distance involving 2 – 3 cells. Thus the sucrose diffuses into the sieve tube elements through the plasmodesmata. Therefore, the concentration of sucrose in sieve tube elements is increased. Mostly, the sucrose takes symplast pathways. In some cases, apoplast movement also takes place.

3. Increase of hydrostatic pressure in sieve tube elements

Water moves into the leaf vein from the nearby xylem. This increases the hydrostatic pressure of the sieve tube element.

4. Movement from sink to source

The hydrostatic pressures put pressure on the sucrose solution. So the sucrose and other substances are moved from sieve tube cells into the sink like fruits. The storage sinks like sugar beet root and sugarcane stem take a different pathway. In this case, the sucrose is removed into apoplast pathways before entering into the symplast of the sink.

5. Absorption of sucrose by the sink

Water is moved out of the sieve tube cells by osmosis. It reduces the hydrostatic pressure in the sieve tube cells. The sucrose moves through the plasmodesmata in the symplast pathways. The sucrose enters into the sieve tubes of the sources. On the other hand.

sucrose is removed from the sink. So a concentration gradient is developed between the source and sink. It develops high osmotic pressure in the sieve tube cells of the source. Thus there is steep drop in the water potential of the source sieve tube cells.

6. Pressure gradient between source and sink

The sieve plates greatly increase the resistance in the pathways. This resistance generates and maintains a substantial pressure gradient in the sieve elements between the source and sink.

The contents of sieve elements are pushed along the transportation pathways by bulk flow. This bulk flow is like water flowing through garden hose.

The pressure flow theory explains the mechanism of mass flow of molecules within the phloem. The carbohydrates are moved from mesophyll cells into the phloem tissue by diffusion and active transport. Then transportation of material within the phloem tissues takes place by pressure flow theory.

Again the sugar (or other carbohydrates) is passed from the phloem tissues into the sink. It takes place by diffusion, active transport or carrier mediated transport.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Diffusion	The movement of molecules from higher concentration to lower concentration is called diffusion.
Chemical potential	The total kinetic energy of the molecules is called chemical potential.
Graham's law	It states that the rates of diffusion of gases are inversely proportional to the square roots of their densities.
Diffusion pressure	The pressure exerted by the diffusing particles is known as diffusion pressure.
Imbibition	The special type of diffusion in which an imbibant absorbs water on its surface without dissolving in it is called imbibition.
Imbibition pressure	The force generated by the imbibants is called imbibition pressure or metric potential.
Osmosis	The movement of solvent molecules from the region of higher concentration to the region of lower concentration through semi permeable membrane is called osmosis.
Osmotic pressure	The maximum pressure that develops when a solution is separated from its solvent by a semi permeable membrane is called osmotic pressure.

Water potential	The chemical potential of water is called water potential. The total kinetic energy of the molecules is called water potential.
Solute potential	The decrease in water potential due to dissolution of solute molecules or ions in water is called solute potential.
Matric potential	The decrease in the water potential due to affinity of water molecules with the colloidal substances (protoplasm and cell wall) is called matric potential.
Pressure potential	The turgor pressure (TP) exerted by the vacuole is called pressure potential.
Soil	The complex composite mass made up of both inorganic and organic, components containing water and air is called soil.
Soil texture	Relative proportion of the soil particles size is known as soil texture.
Run away water	Some of the water drains away along the slopes after a heavy rainfall or irrigation. This is called run-away water.
Field capacity of soil	The amount of water retained by soil after the removal of excess water by gravitation is called the field capacity or the water holding capacity of the soil.
Hygroscopic water	Water adsorbed on the surface of soil colloids is called hygroscopic water.
Capillary water	The water which fills the spaces between the non colloidal smaller soil particles is called capillary water.
Water table	The water level at some depth from the soil where all pore spaces are filled with water is called water table.
Wilting coefficient	The amount of moisture left in the soil after a plant has permanently wilt is called wilting coefficient.
Apoplast pathway	The movement of water molecules through the adjacent cell walls is called apoplast pathway.
Symplast pathway	The movement of water through the protoplast of the plant cells is called symplast pathway.
Root pressure	The hydrostatic pressure generated in the root which forces the water upward in the stem is called root pressure.
Capillary tube	A glass tube with a narrow bore is called a capillary tube.

Cohesion tension theory	This theory states that the negative pressure or pull or suction is created in the leaves as a result of transpiration pulls the water upward.
Adhesion	The attraction between the water molecules and the cell wall of the xylem cells is called adhesion.
Transpiration	The evaporation of water from the aerial part of plant is called transpiration.
Saturation deficit	Saturation deficit is the difference between the amount of water vapour actually present in the air and the amount necessary to completely saturate it.
Absolute humidity	The amount of moisture actually present in the air is called its absolute humidity
Relative humidity	The percentage of the amount of moisture necessary for saturation at a particular temperature is called relative humidity.

MODEL SUBJECTIVE QUESTIONS

1. **What is diffusion? Give factors affecting the rate of diffusion.**
2. **What is imbibition? Give its significance?**
3. **What is osmosis? Give its demonstration.**
4. **Give factors affecting osmosis.**
5. **Describe water relations.**
6. **What is soil? Give its texture and profile.**
7. **Write note on soil water.**
8. **Describe mechanism of water absorption.**
9. **Give factors affecting water absorption.**
10. **What is ascent of sap? Give role of root pressure and capillary in ascent of water.**
11. **Describe Cohesion Tension theory.**
12. **What is transpiration? Give its demonstration.**
13. **Give factors affecting rate of transpiration.**
14. **Describe structure of stomata.**
15. **Describe mechanism of opening and closing of stomata.**

SHORT QUESTIONS

1. What is diffusion? Give one example.

Ans: The movement of molecules from higher concentration to lower concentration is called diffusion. Oxygen is utilized and carbon dioxide is removed during respiration in a leaf. This CO_2 collects in the intercellular spaces of the leaf. Carbon dioxide diffuses from the intercellular spaces into the outer air. But oxygen diffuses in the reverse direction.

16. **What is Graham's law of diffusion? Write its equation.**

Ans: **It states that the rates of diffusion of gases are inversely proportional to the square roots of their densities.** Graham's law is applied on the diffusion of gases.

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

3. **What are imbibition and imbibant?**

Ans: The special type of diffusion in which an imbibant absorbs water on its surface without dissolving in it is called imbibition. Imbibant is a hydrophilic surfaces like protein, starch or clay.

4. **Give two significance of imbibition.**

Ans: Dry plant material like dry wood is placed in water. It swells and its volume increases. Dry pea seeds are placed in water. These also swell. It helps in the germination of seed.

17. **Differentiate between osmotic pressure and turgor pressure.**

Ans: The maximum pressure that develops when a solution is separated from its solvent by a semi permeable membrane is called osmotic pressure. The pressure exerted by the cell sap on the cell wall of plant cell is called turgor pressure.

8. **What are water and solute potentials?**

Ans: The chemical potential of water is called water potential. The total kinetic energy of the molecules is called water potential. The decrease in water potential due to dissolution of solute molecules or ions in water is called solute potential.

9. **Water is matric potential?**

Ans: The decrease in the water potential due to affinity of water molecules with the colloidal substances (protoplasm and cell wall) is called matric potential.

10. **What is soil?**

Ans: The complex composite mass made up of both inorganic and organic, components containing water and air is called soil.

12. **Give composition of soil.**

Ans: Soil has following composition.

Material	Composition
Mineral matter	40 per cent
Organic matter	10
Water	25
Air	25

13. **What is clayey soil? Give its advantage.**

Ans: The soil consists mainly of clay particles are called clayey soils. The clay particles are mostly of colloidal nature. They possess high water holding properties.

14. **Differentiate between soil texture and soil profile.**

Ans: Relative proportion of the soil particles size is known as soil texture. The arrangement of soil particles in layers is called soil profile.

15. **What is run away water? Give its significance for plant**

Ans: Some of the water drains away along the slopes after a heavy rainfall or irrigation. This is called run-away water. It is not available to the plant.

16. What is field capacity?

Ans: The amount of water retained by soil after the removal of excess water by gravitation is called **the field capacity** or **the water holding capacity** of the soil.

17. What is hygroscopic water?

Ans: Water adsorbed on the surface of soil colloids is called hygroscopic water.

18. What is water table?

Ans: The water level at some depth from the soil where all pore spaces are filled with water is called water table.

19. What is Wilting coefficient or permanent wilting point?

Ans: The amount of moisture left in the soil after a plant has permanently wilt is called wilting coefficient.

20. What is the significance of soil air for plant?

Ans: The soil particles are irregular in size and shape. Therefore, interspaces are present between them. These interspaces are filled by air or partly by water. This soil air is essential for the proper growth of plant.

21. What are Casparian strips? What is its significance?

Ans: The transverse and radial cell walls of endodermal cells have **Casparian strips**. These strips are characteristics cell wall thickenings. These are impregnated with **suberin**. Suberin is impermeable to water. Therefore, the water with its dissolved substances cannot pass out of endodermal cells.

22. Differentiate between apoplast and symplast pathways.

Ans: The movement of water molecules through the adjacent cell walls is called apoplast pathway. The movement of water through the protoplast of the plant cells is called symplast pathway.

23. What is mycorrhiza? Give its significance for plant.

Ans: Mycorrhizae is an association of fungi and roots of higher plants. Fungi increase the ability of absorption of water by roots.

24. What is root pressure?

Ans: The hydrostatic pressure generated in the root which forces the water upward in the stem is called root pressure. Root pressure forces the water up from below.

25. What is cohesion tension theory?

Ans: This theory states that the negative pressure or pull or suction is created in the leaves as a result of transpiration pulls the water upward.

26. Differentiate between Absolute humidity and Relative humidity.

Ans: The amount of moisture actually present in the air is called its absolute humidity. The percentage of the amount of moisture necessary for saturation at a particular temperature is called relative humidity.

27. What is role of wind in transpiration?

Ans: Wind has a powerful effect on humidity. Dry wind removes the moist air from the immediate vicinity of the plants. It lowers the amount of air moisture near plant. As a result, the humidity of the air is lowered. It promotes transpiration.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. The pressure exerted by the diffusing particles is ________ pressure.
(a) Solute (b) Diffusion (c) Imbibtion (d) None

2. Which of the following is an imbibant?
(a) Milk (b) clay (c) Leaf (d) Sugar

3. The maximum pressure that develops when a solution is separated from its solvent by a semi permeable membrane is called:
(a) Diffusion (b) Osmotic (c) Solute (d) Turgor

4. The pressure exerted by the cell sap on the cell wall of plant cell is called turgor pressure.
(a) Diffusion (b) Osmotic (c) Solute (d) Turgor

5. The decrease in water potential due to dissolution of solute molecules or ions in water is potential.
(a) Osmotic (b) Matric (d) Water (d) Pressure

6. The turgor pressure (TP) exerted by the vacuole is called pressure potential.
(a) Osmotic (b) Matric (d) Water (d) Pressure

7. Percentage of minerals present in soil is:
(a) 10 (b) 30 (c) 40 (d) 60

8. The size of coarse sand is:
(a) 2.00—0.20 (b) 1.00—0.20 (c) 2.00—1.20 (d) None

9. Water adsorbed on the surface of soil colloids is water.
(a) Capillary (b) Hygroscopic (c) Gravitational (d) None

10. The water which fills the spaces between the non colloidal smaller soil particles is water.
(a) Capillary (b) Hygroscopic (c) Gravitational (d) None

11. Casparian strips are present in:
(a) Endodermis (b) Epidermis (c) Xylem (d) Cortex

12. The hydrostatic pressure generated in the root which forces the water upward in the stem is pressure.
(a) Diffusion (b) Osmotic (c) Root (d) Turgor

13. The factor which decrease transpiration is:
(a) Water (b) Humidity (c) Wind (d) Light

14. Starch sugar hypothesis was put forward by:
(a) Dixon (b) Sayre (c) Robert (d) none

Answers: 1. (b) 2. (b) 3. (b) 4. (d) 5. (a) 6. (d) 7. (c) 8. (a) 9. (b) 10. (b) 11. (a) 12. (c) 13. (b) 14. (b)

Fill in blanks

1. The total kinetic energy of the molecules is called __________ potential.
2. The pressure exerted by the diffusing particles is known as _________ pressure.
3. The special type of diffusion in which an ______ absorbs water on its surface without dissolving in it is called imbibition.
4. The movement of solvent molecules from the region of higher concentration to the region of lower concentration through semi permeable membrane is called __________.

5. The pressure exerted by the cell sap on the cell wall of plant cell is called ________ pressure.
6. The chemical potential of water is called water potential. The total kinetic energy of the molecules is called _______ potential.
7. The decrease in water potential due to dissolution of solute molecules or ions in water is called _________ potential.
8. The complex composite mass made up of both inorganic and organic, components containing water and air is called ________.
9. The amount of water retained by soil after the removal of excess water by gravitation is called _________ soil.
10. Capillary water: The water which fills the spaces between the non colloidal smaller soil particles is called _______ water.
11. The water level at some depth from the soil where all pore spaces are filled with water is called ________ table.
12. The transverse and radial cell walls of endodermal cells have _________ strips.
13. The movement of water molecules through the adjacent cell walls is called _________ pathway.
14. The hydrostatic pressure generated in the root which forces the water upward in the stem is called _________ pressure.
15. Attraction between water molecules and cell wall of the xylem cells is called ______.

Ans: 1. chemical 2. diffusion 3. imbibant 4. osmosis 5. Turgor 6. water
7. solute 8. soil 9. field capacity10. capillary 11. water
12. Casparian 13. apoplast 14. root 15. adhesion

True/False

1. The movement of molecules from higher concentration to lower concentration is called diffusion.
2. The total kinetic energy of the molecules is called osmotic potential.
3. The special type of diffusion in which an imbibant absorbs water on its surface without dissolving in it is called osmosis.
4. The maximum pressure that develops when a solution is separated from its solvent by a semi permeable membrane is called osmotic pressure.
5. The decrease in the water potential due to affinity of water molecules with the colloidal substances (protoplasm and cell wall) is called matric potential.
6. The decrease in water potential due to dissolution of solute molecules or ions in water is called pressure potential.
7. The complex composite mass made up of both inorganic and organic, components containing water and air is called soil.
8. Humus and clay form solution complex of the soil.
9. The transverse and radial cell walls of endodermal cells have Casparian strips.
10. The movement of water molecules through the adjacent cell walls is called apoplast pathway.
11. The downward movement of water in a plant is called-the ascent of sap.
12. The evaporation of water from the aerial part of plant is called transpiration.

Ans: 1. T 2. chemical 3. imbibition 4. T 5. T 6. Solute
7. T 8. colloidal 9. T 10. T 11. upward 12. T

Chapter 3

MINERAL UPTAKE (MINERAL NUTRITION

Syllabus

1. Soil as a source of minerals
2. Passive and active transport
3. Essential mineral elements their role and deficiency symptoms with emphasis on Ca, N, K and P.

SOIL AS A SOURCE OF MINERALS

The soil consists of mineral and organic matter. The mineral matter consists of pebbles, sand and clay. The organic matter consists of dead and decomposed remains of plants and animals. It is called humus. The clay and humus and soil solution are important source of minerals.

1. **Clay and humus:** Clay is an inorganic material. It consists of aluminum and silicon oxides. Humus consists of carbonaceous residue. It is derived from lignin of cell walls. Both clay and humus particles are similar in size. They are hydrophilic colloids. The surface of these particles is negatively charged. So they can absorb cations like calcium, potassium, magnesium and others.
2. **Soil solution:** Soil solution contains both cations and anions:
   - **(i) Cations:** Some cation is dissolved in the soil solution. Mostly root of plants absorbs these ions. A dynamic equilibrium is maintained between the cations present in the soil solution and the ions adsorbed on the colloidal particles. The plant root takes up ions. Therefore, the soil solution becomes deficient in cations. So the colloids (clay and humus) release cations and replenish the soil solution. Therefore, the soil colloids constitute a reserve source of cations.
   - **(ii) Anions:** Anions like nitrate, phosphate and sulphate are not adsorbed on the colloids. Therefore, they are present only in the soil solution. Therefore, anions are easily leached out with irrigation or rain water. Thus it is necessary to frequently replenish the anions by fertilizers.

PASSIVE ABSORPTION OF MINERALS

The movement of minerals into the cell or tissue without the expenditure of energy is called passive absorption. This is a physical phenomenon. Passive absorption takes place by following ways:

(a) DIFFUSION

The concentration of ions inside the root cells is several times more than in the soil solution. Secondly the mineral has to cross several barriers before entering the cells of the root. The refore, mineral ions cannot directly move from the soil solution into the cells of the root by simple diffusion. They can pass through only from the free space by diffusion. The first barrier is the cell wall. Cell wall is permeable for the entry of ions. Therefore, they can freely pass through it by simple diffusion. After crossing the cell wall, the ions freely move. They come across the cell membrane called ectoplast. It prevents further movement of ions by diffusion. It means ions can freely move from the soil solution up to this barrier. The term **free space** is used for the part of the plant cell and tissue where ions can freely move by diffusion. It is also called **apparent free space (AFS)**. The inner boundary of free space is the ectoplast. Entry of ions into free space is very fast and it takes place by diffusion. Ions can also easily diffuse out.

Therefore, ions can pass through free space area by diffusion. Ions cannot cross the barrier of ectoplast by this process and enter the protoplasm.

(b) MASS FLOW

The movement of ions along with bulk amount of water is called mass flow of ions. The increase of transpiration also increases the absorption of ions from the soil. Cohesion tension theory explains the role of transpiration in the mass movement of water. It is believed that mineral ions also move into the root along with this mass flow of water. Some physiologists believe that the effect of transpiration on mineral absorption is indirect. Transpiration removes the minerals from the root xylem with the transpiration stream. So it reduces its concentration in the root cells. As a result, root absorbs more minerals from the soil.

(c) MECHANISM OF IONIC EXCHANGE

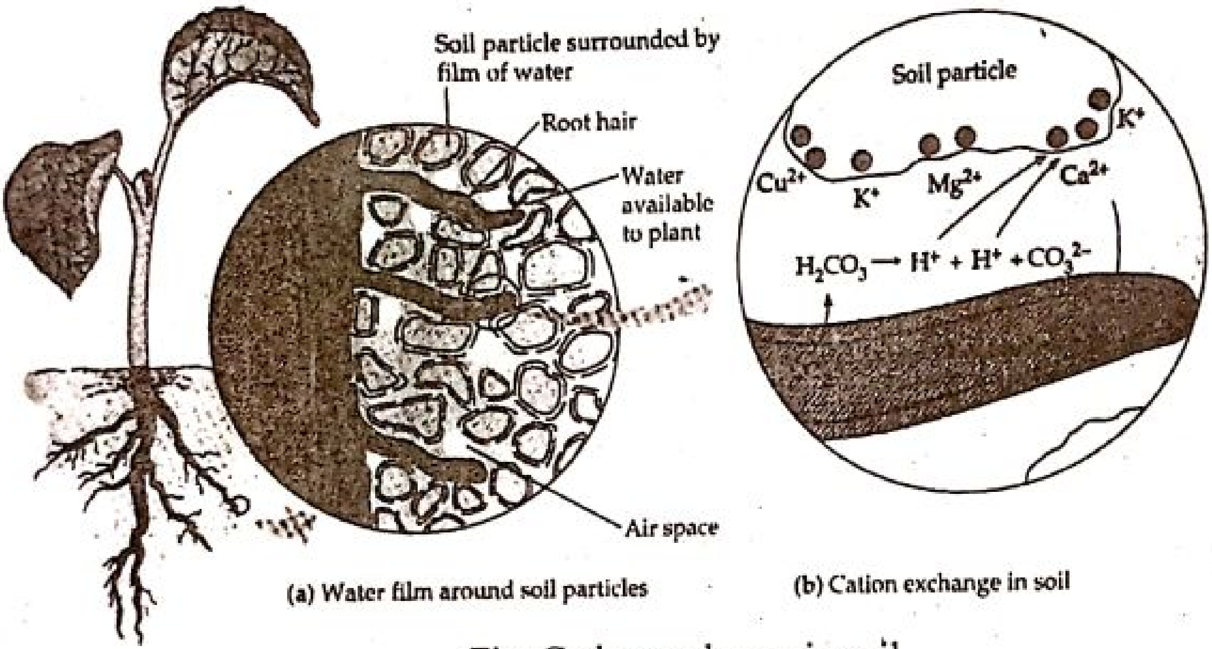
The exchange of anions or cations of the cells with the ions of the same and equivalent charge of outer solution is called ion exchange. The ion exchange does not require metabolic energy. Therefore, it is a passive physical process. Thus it is not affected by the rate of aerobic respiration. There are two theories explaining the mechanism of ion exchange. These are (i) contact exchange theory and (ii) carbonic acid exchange theory

(i) Contact exchange theory

According to this theory, ions are not dissolved in water. The roots are present near the clay particles in the soil. Cations are adsorbed on surface of the clay colloids. The roots releases H^+ ion. These H^+ ions are directly exchanged by the cations of clay particles.

(ii) Carbonic acid exchange theory

According this theory, ions first dissolve in the soil solution. Carbon dioxide released during the respiration in roots. It dissolves in soil water and form carbonic acid (H_2CO_3). Carbonic acid is a weak acid. It dissociates into H^+ ions ad HCO_3^- ions. H^+ ion ions reach the clay particles. They are exchanged with cation like K^+ present in the soil. The released cation goes into the soil solution. Finally they reach the root surface.



(a) Water film around soil particles

(b) Cation exchange in soil

Fig: Cation exchange in soil

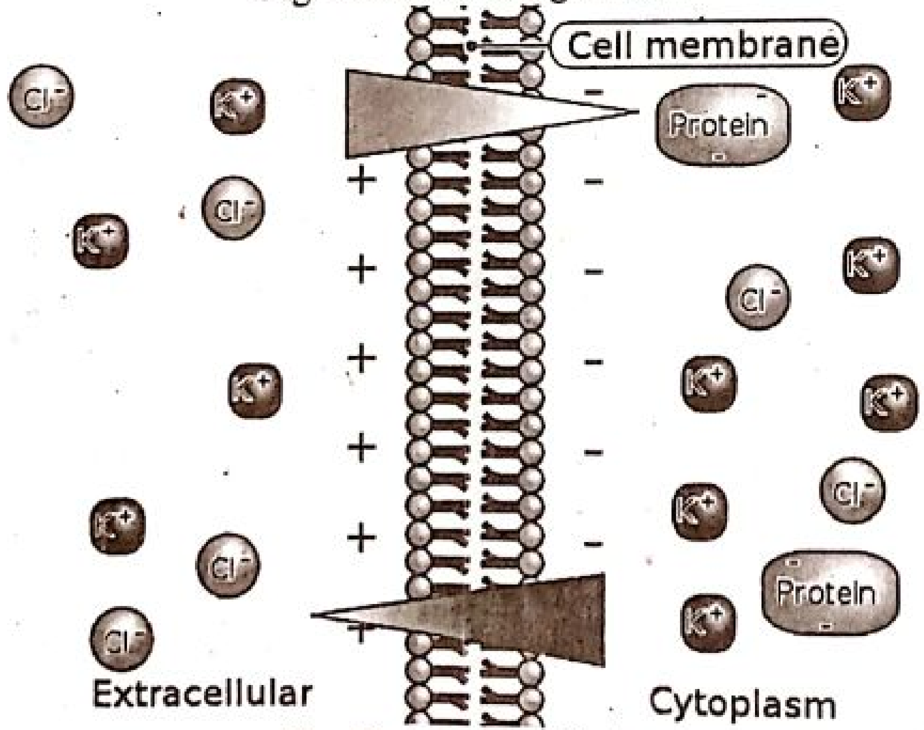


Fig: Donnan Equilibrium

(d) DONNAN EQUILBRIUM

The equilibrium of ions between root cells and soil solution in the presence of fixed ions in the root cells is called Donnan equilibrium. Suppose a cell contains potassium proteinate (K^+ and Pr^- protein ions). It is immersed in an external solution. This solution contains potassium chloride. Inside the cell are K^+ and Pr^- ions. The outer solution contains K^+ and Cl^- ions. The plasma membrane is freely permeable to Cl^- and K^+ ions. But it is impermeable to Pr^+ ions. Pr ion is thus called fixed anions.

Cl^- will diffuse into the cell across the membrane due to difference of concentration. An equal number of K+ ions accompany them to neutralize them. This will continue till equilibrium is reached. Additional cations (K^+) are needed to neutralize the negative charges of the fixed anions (Pr–). Therefore, the concentration of K^+ inside the cell is greater than the external solution at equilibrium point. Thus cations are accumulated in the cell at a higher concentration than in the external solution. It does not need expenditure of metabolic energy. This equilibrium is called **Donnan equilibrium**. Similarly, if there are fixed cations on the inside of the cell membrane it will accumulate anions in the cells.

ACTIVE ABSORPTION OF MINERALS

The concentration of mineral solutes is much higher in the absorbing cells than outside in most cases. This increased concentration of minerals in the cells is called **solute accumulation**. Salt accumulation is a selective process. Absorption in such cases takes place against a concentration gradient. The theory of active solute absorption was put forward by **Hoagland** (1923) and others. According to this theory, the absorption of mineral salts takes place against a concentration gradient. The pumping up of salts is a continuous process. It causes accumulation of ions in cell. The rapid absorption of an anion retards the absorption of other anions. It promotes the absorption of a cation. Similarly rapid absorption of a cation inhibits the absorption of other cation. But it increases the absorption of an anion. Active absorption requires a continuous expenditure of energy. This energy is supplied by the adenosine triphosphate (ATP). ATP is produced in the respiratory activity of the root cells. Following factors promotes the active transport:

1. Respiration is the essential conditions for the absorption of salts and their accumulation. Therefore, this process is confined to growing and dividing cells. Meristematic cells and enlarging cells are the most active in absorbing ions. They lose the power of salt accumulation with stoppage of growth. The capacity for salt accumulation decreases from backward of the tip of root.
2. Lack of oxygen inhibits respiration. It also decreases the rate of absorption of ions.
3. Adequate supply of respiratory material and favourable temperature also promote salt absorption.
4. Photosynthesis supply carbohydrates for respiration. Therefore, salt accumulation is also affected by the rate of photosynthesis.

Mechanism of Active absorption

Following mechanisms are involved in the active absorption of minerals:

1. **Proton pump:** Proton pump is present in the membrane of the root cells. It is an **electrogenic pump**. A transport protein, that generates voltage across a membrane is called electrogenic pump. It is called **electrogenic transport**. It uses ATP. Proton pump actively transport hydrogen ion of the cell. It also creates membrane potential in the cells. It set proton gradient across the membrane of cell. This gradient enforces the minerals inside. Proton pump works as follows:

a) Proton pump uses energy from ATP. This energy pumps hydrogen ion (H^+) out of the cell.

b) This pumping of ions out of the cell creates a proton gradient. Now there is higher concentration of H^+ outside the cell than inside.

c) The separation of opposite charges across membrane creates membrane potential in the form of potential energy.

d) Now membrane potential is used to drive the transport of many minerals inside the cells.

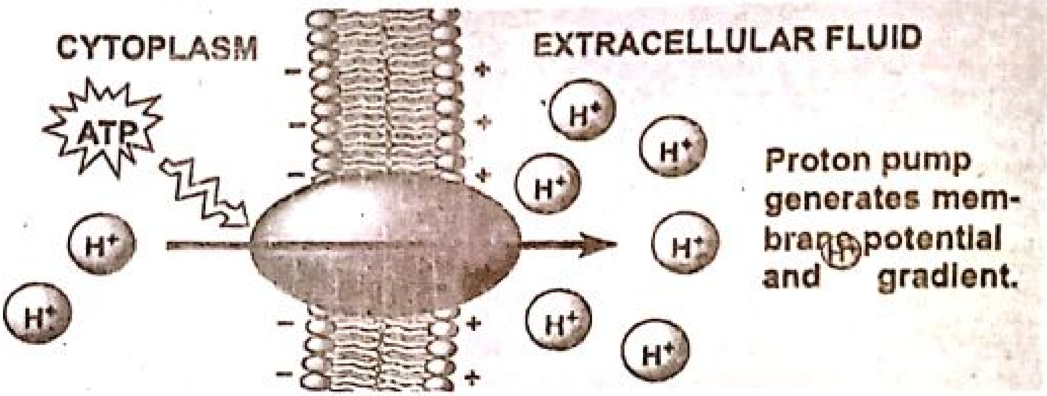
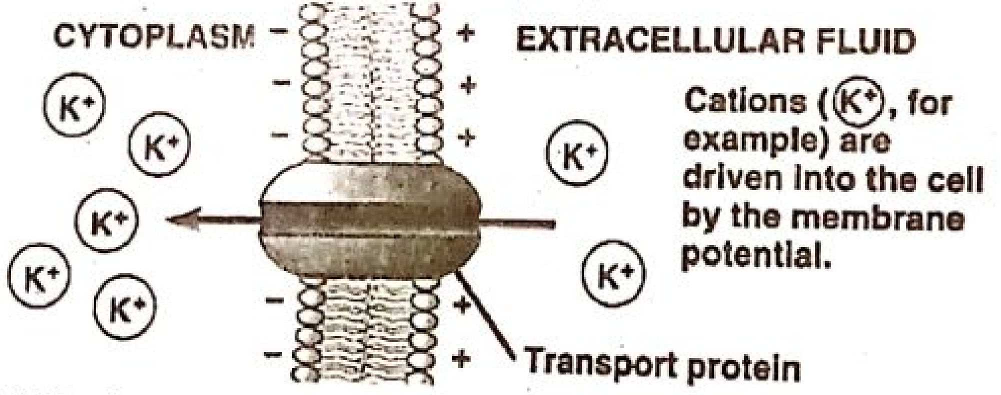
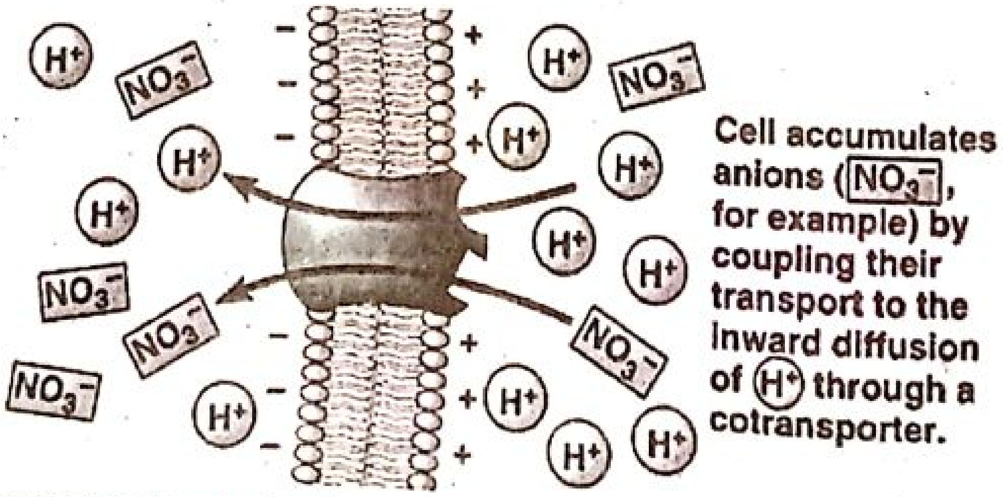


Fig: Proton pump


CYTOPLASM
EXTRACELLULAR FLUID
K+
Cations (K+, for example) are driven into the cell by the membrane potential.
Transport protein

(a) Membrane potential and cation uptake


H+
NO3−
Cell accumulates anions (NO3−, for example) by coupling their transport to the inward diffusion of H+ through a cotransporter.

(b) Cotransport of anions

Fig: Cotransport

2. **Cotransport: The transport by which a substance indirectly drives the active transport of several other solutes is called contransport.** A substance that is pumped across a membrane has potential energy. It can leak back to the cell. Thus energy is released. Another specialized transport protein uses this energy and transport another mineral against concentration. Cotransport may be:
   (i) **Antiprot:** In this case, the two transported molecules moves in opposite direction.
   (ii) **Symport:** In this case, two molecules move in the same direction.

FACTORS AFFECTING ABSORPTION

1. Soil aeration

Living cells cannot survive without oxygen. The roots contain a large number of living cells. Thus they require considerable amount of energy. This energy is used for their metabolic activities and growth. So oxygen is essential for generating energy rich components. It occurs by biological oxidative process. Mineral absorption requires energy. Therefore, poor soil aeration affects the ability of roots to absorb minerals. Water logged soils or soils with higher content of clay have very little amount of air. Thus roots are subjected to anaerobic conditions. So absorption of minerals is drastically affected.

2. Temperature

Soil temperature has a significant effect on roots metabolic activities. It also affects the mobility of ions in soil solution. Absorption of minerals is much reduced at lower temperature. The rate of absorption increases with increase in temperature. But It is up to certain limits.

3. pH of the soil solution

Ionization of minerals and other nutrients occur. It depends upon hydrogen ion concentration of the soil solution. For example, most of the phosphate ions, at alkaline pH exist either as bivalent H_3PO_4 ions or trivalent H_3PO_4 ions. Such ions are not favored for absorption. But neutral pH favors the absorption of monovalent ions. So the soil pH has a significant effect on rate and kind of ions uptake. Proteins are involved in the ion uptake. Protein structure is very sensitive to pH. Its function changes if there is any change in the pH. That is why the maintenance of proper soil pH is very important in agriculture. Too acidic or too alkaline soil is useless for cultivation.

4. Concentration of soil solution

Concentration of minerals in soil solution is far less than in the cell sap. Thus absorption of ions takes place against concentration gradient. The relative concentration of ions in cell sap and soil solution gives **absorption ratio.**

Ocean water contains greater amount of salts than that of fresh waters. The marine water is enriched with greater amount of metal ions. Therefore, land plants die in marine water. It is physiologically dry for them. But marine plant cells are adapted to such waters. They contain more ionic contents than found in sea water. Even here, ions are absorbed against concentration gradient.

The rate of absorption of ions depends upon concentration of the soil solution. Roots absorb greater amount of ions in dilute solutions than in high concentration solutions.

5. Ion-ion interactions

Soil solution consists of a wide variety of ions. These ions are present in different concentrations. But roots absorb inorganic nutrients. The ions of different kinds are present in the solution. These ions may facilitate or interfere with the uptake of the other kind of ions. This phenomenon is called **ion antagonism**. Some ions enhance the uptake of another kind of ions. Such a phenomenon is called as ion **facilitated uptake.**

Epstein found that calcium and magnesium bivalent ions antagonize the absorption of K and Fe. Similarly $CaCl_2$ inhibit the uptake of Cu^{2+} ions. Sodium chloride facilitates the uptake a wide variety of ions.

ESSENTIAL ELEMENT

The elements which are needed by the plants for normal and healthy life are called essential elements. Only 16 elements are essential elements. There are two types of essential elements:

1. **Macronutrients or major elements:** These elements are required by the plants in large quantity. The major elements are C, F, O, N, S, P, Ca, K and Mg.
2. **Micronutrients or trace elements:** The remaining 7 elements are required in small quantity. These are called trace micronutrients. The micronutrients are Fe, Mn, B, Cu, Zn, Mo and Cl.

Important functions and deficiency symptoms of mineral elements

Element	Function	Deficiency syndrome
Nitrogen	Constituent of: Proteins Chlorophyll Nucleic acids Cell membranes	1. Stunted growth, 2. Leaf chlorosis 3. Leaf shedding 4. Purple vein formation in tomato 5. Poor flowering and fruiting
Sulphur	Constituent of: Amino acids: Methioninine Cystine, Cysteine Vitamins: Biotin, Thiamine Coenzyme, Sulphydrill bonds of Proteins	1. Leaf chlorosis along with Leaf roiling, 2. Leaf shedding. 3. Younger leaves affected first 4. Inhibition of terminal buds 5. Emergence of lateral bud
Phosphorus	Constituent of: Proteins, Nucleic acids Cell membranes ADP, ATP, NADP Takes part in Energy transactions	1. Leaf chlorosis 2. Leaf curling 3. Death of root and shoot tips 4. Shoot branching bushy

	Oxidation-reduction	habit 5. Stunted growth 6. Poor nodulation in legumes
Calcium	Constituent Middle lamella Necessary for: Structural integrity of chromosomes and membranes Cell division	1. Leaf chlorosis 2. Leaf curling 3. Death of root and shoot tips 4. Shoot branching and bushy habit 5. Poor flowering and fruiting
Potassium	Activator of several enzymes Takes part in: Respiration Protein synthesis Carbohydrate metabolism Stomatal opening and closing	1. Stunted growth 2. Die back of young shoot 3. Poor development of mechanical tissues 4. Chlorotic and necrotic leaf margin 5. Older leaves affected first
Magnesium	Constituent of chlorophyll Necessary for: Membrane integrity Integrity of ribosomes Protein synthesis Nucleic acid synthesis Activator of decarboxylases	1. Leaf chlorosis 2. mottling and wilting 3. Leaf necrosis 4. Leaf shedding 5. Older leaves affected first
Iron	Constituent of: Ferredoxin, Cytochromes, Catalase peroxidases Leghaemoglobin Necessary ion chlorophyll formation Electron transport chain	1. Interveinal chlorosis of leaves 2. Necrotic pots on leaves. and stem 3. Young leaves affected first
Manganese	Activator of enzymes: Oxidases, Peroxidases, Dehydrogenases, Decarboxylases, Necessary for: Chlorophyll formation Nitrogen metabolism	1. Mottled leaf chlorosis 2. Leaf necrosis 3. Browning and withering of leaves
Boron	Take part in: Carbohydrate metabolism, Calcium and phosphorus metabolism, pollen germination and fertilization	1. Stunted growth 2. Death of root and shoot apices 3. Shoot branching Stumpy

		root, Necrotic leaf shedding 4. Inhibition of flowering and fruiting
Copper	Constituent of enzymes: AA oxidases, Cytochrome oxidase, Tyrosinase, Phenolase Constituent of electron carrier, Plastocyanin, Plastoquinone	1. Yellowing of leaf tip 2. Leaf necrosis 3. Wilting of terminal shooting
Zinc	Activator of enzymes: Alcohol dehydrogenation Carbonic anhydrase Carboxy peptidase Essential for Tryptophan synthesis and auxin synthesis	1. Leaf margin and tip chlorosis 2. Leaf mottling and necrosis 3. Stunted growth 4. Failure of seed setting
Molybdenum	Activator of enzymes: Dehydrogenase, Nitrate reductase Constituent of: Nitrogenase	1. Mottling and curling of leaves, 2. Failure of nodulation, 3. Failure of leaf expansion, 4. Flower shedding
Chlorine	Activator of enzymes concerned with photolysis of water	1. Wilting of leaf 2. Leaf chlorosis 3. Stunted root growth

NITROGEN

1. The chief source of nitrogen is the nitrate ion of the soil. Plants also uses nitrites and ammonia salts. Certain bacteria can utilize atmospheric nitrogen. The leguminous plants like pea and bean are the hosts of symbiontic bacteria. These bacteria inhabit the roots of these plants and form root nodules. The root nodules bacteria fix nitrogen in soil air. They convert this nitrogen into amino acid. These amino acids are used by the host plant.

Physiological role

1. Nitrogen is an essential component of proteins and nucleic acids.
2. It is also an important component of chlorophyll.
3. It promotes cell division and cell enlargement.
4. It increases respiratory rate.

Deficiency Symptoms

1. **Yellowing of leaves or chlorosis:** The yellowing of leaf especially older leaves near the base of plant is called chlorosis. Leaves turn yellow and start falling. These effects

appear first in the older leaves.

2. **Anthocyanin formation:** In many species, like tomato, leaf veins turn purple or red due to anthocyanin formation.
3. **Changes in nutrients contents:** The starch contents are increased due to its deficiency. But there is a decrease in the protein content. There is accumulation of carbohydrates in woody stems. Carbohydrates cannot be used in synthesis of amino acids and proteins. Therefore, plant growth remains stunted
4. **Low rate of respiration:** There is shortage of enzyme of respiration due to low level of nitrogen. Enzymes are protein in natures. Nitrogen is essential constituent of proteins. Thus respiration slows down in nitrogen deficient plants.
5. **Dormancy of lateral bud:** The lateral buds remain dormant.
6. **Effect on flowers, seeds and fruits:** Flower formation is delayed or suppressed. If flowers are formed, the fruits and seeds remain small and weak.
7. **Plant Stunting**: Nitrogen is essential for cell division and enlargement. When it is lacking, plants will be shorter than usual. The leaves may be smaller. Maturity of plant may also be delayed.
8. **Older tissue affected first:** When there is a N shortage in the plant, N-containing compounds in the older tissue break down. They move to the younger leaves. This causes nitrogen deficiency. It is first noticeable in the tips and margins of older leaves. The entire plant appears **chlorotic** in severe deficiency.
9. **Protein loss**: Many crops have less visible nitrogen deficiency symptoms. These are lower protein content and less plump seeds. Such symptoms do not become obvious until after harvest.

Excess supply of nitrogen

Excess supply of nitrogen causes abundant vegetative growth and poor flowering. The insects and pathogen attack on plant. The stem becomes weak and tender. The leaves become dark-green and succulent. Excess nitrogen inhibits the development of mechanical tissues like sclerenchyma.

CALCIUM

Calcium is absorbed as calcium ions Ca^{2+}. A large amount of calcium is present in most of the soils. But there acidic soils are deficient of calcium.

Physiological role

Calcium is essential for all plants. It is rich in the older tissues.

1. Calcium is deposited in the cell wall in the form of calcium pectate. Calcium pectate forms middle lamella. Cell wall remains weak without this compound.
2. Calcium concentrates around the chromosomes. It plays role in binding of nucleic acid to protein.
3. Calcium is necessary for cell division.
4. It stimulates the development of root hairs. It promotes the activity of chloroplasts.
5. It promotes the movement and utilization of carbohydrates and amino acids in the plant.

6. Calcium help in neutralizing acids like oxalic acid, both inside and outside the plant.
7. Sometimes, crystals of calcium sulphate and calcium oxalate are found in plant cells.

Deficiency symptoms

It has following deficiency symptoms:

1. **Chlorosis:** Chlorotic patches appear near the leaf margin in young leaves. The young leaves become deformed.
2. **Effects on root and shoot tips:** Calcium deficiency causes rapid disintegration of the growing tips of roots and shoots in many plants.
3. **Effects on seed formation:** Its deficiency inhibits seed formation.
4. **Effects on cells wall:** Calcium strengthens cell walls. So as cells weaken.
5. **Effect on vascular system:** The vascular system of the plant starts to collapse. It reduces the uptake of all of the major elements. The symptoms show up first at the growing tips of both the shoots and the roots.
6. **Problem of translocation of calcium:** Calcium is an immobile element. It means that when there is a deficiency, plant cannot translocate calcium from the older leaves to the younger leaves. New growth at the leaf tips and margins begins to wither and die. The new leaves are often deformed.
7. **Effects on roots:** The most serious effect of calcium deficiency occurs in the roots. Calcium is involved in root extension. Calcium is necessary for the secretion of protective mucilage around the root caps. Root diseases causing fungi like *Pythium* can attack such roots. Roots often become stunted without enough calcium. They are discoloured. They begin to leak the solutes that plants need to grow. This results in a thin, spindly root system. It often becomes a slimy brown or black, especially at the root tips. There is lacking of actively growing roots. Now any of the other nutrient deficiencies can appear.
8. **Magnesium toxicity:** Deficiency of calcium causes high uptake of magnesium. Higher amount of magnesium in plants causes magnesium toxicity.

POTASSIUM

Potassium is need in comparatively in smaller amount to plants. But still most of our soils are deficient in potassium. Therefore, potassium fertilizers are excessively used in fields.

Physiological role

The plants need potassium in large quantities. It plays following physiological roles:

1. It provides the necessary ionic balance. This ionic balance is necessary for the survival of plant.
2. It plays an important role in the plant metabolism. It acts as an activator of many plant enzymes.
3. It promotes the growth of apical meristem, secondary roots and newly developing leaves.
4. Potassium is essential for the synthesis and translocation of carbohydrates in plants like sugar beets and potatoes. It is essential for the enzymatic hydrolysis of starch.
5. Potassium control respiration in some way.

6. It is necessary for opening and closing of stomata.
7. Plant requires potassium ions (K^+) for protein synthesis.
8. Potassium improves the efficiency of water use.
9. It improves resistance to diseases and insects.

Deficiency symptoms

1. **Effects on young shoots and leaves:** Young shoots and leaves start dying due to deficiency of potassium. The foliage leaves are suffered from its deficiency. Their tips take up a scorched appearance. Their margins become dull yellow. The growth of internodes is retarded. Typical symptoms of potassium deficiency in plants include brown scorching and curling of leaf tips and **chlorosis** (yellowing) between leaf veins. Purple spots may also appear on the leaf undersides. Potassium is a mobile nutrient. It means that a plant can transport potassium to younger leaves when it is potassium deficient. Thus potassium deficiency symptoms first appear on older (lower) leaves.
2. **Effect on apical dominance:** Sometimes, the dominance of apical bud is diminished. So the lateral buds start growing. It gives bushy growth. It affects the weight of the grain.
3. **Effect on protein synthesis:** Its deficiency decreases the protein synthesis.
4. **Effect on photosynthesis:** Rate of photosynthesis is reduced due to deficiency of potassium.
5. **Blocking cell division:** The cells fail to divide and instead become elongated. Thus growth remains stunted.
6. **Low resistance to diseases:** Its deficiency reduces resistance to disease. So there is a poor development of mechanical tissue in the stem.
7. **Effect on growth:** Plant growth, root development, and seed and fruit development are reduced in potassium-deficient plants.
8. **Effect on potatoes:** In potatoes, tuber size is much reduced. Thus crop yield is low. The leaves of the plant appear dull. They are often blue-green in color with chlorosis. Leaves will also develop small, dark brown spots on the undersides. A bronzed appearance on the upper surfaces.

PHOSPHORUS

In plants, Phosphorus (P) is second to nitrogen as the most essential nutrient. Phosphorus means for plant is for salts of phosphates (PO_4^{3-}), monohydrogen phosphate (HPO_4^{2-}), and dihydrogen phosphate ($H_2PO_4^-$). These anions readily interconvert. The pH of the solution or soil determines which anion is more dominant in soil.

Physiological roll

1. It is an essential constituent of protein part of the membranes of the cell.
2. It is also part of nucleoproteins, many coenzymes and organic molecules such as ADP, ATP and NADP. These compounds play an important role in the energy transfer reactions of cell metabolism and in oxidation-reduction reactions.
3. It is also necessary for the functioning of mitochondria.

4. Phosphorus is more abundant in the growing and storage organs.
5. It helps in the translocation of carbohydrates.
6. It promotes root growth. It promotes fruit ripening.
7. Phosphorus is necessary for cambial activity. It is essential for reduction of nitrates for protein formation.

Deficiency symptoms

1. **Stunted growth:** Stunted growth is the characteristics symptom of deficiency of phosphorus. Growth is retarded and leaf colour becomes dark-green.
2. **Appearance of dead patches:** Sometimes dead patches appear on leaves, petioles and fruits and the leaves fall early.
3. **Leaf senescence:** The first sign of phosphorus deficiency is premature senescence of older leaves. There is yellowing of leaves. It is preceded by the appearance of purple anthocyanin pigments in leaves. Yellowing may spread from discrete interveinal patches. It often affects one half of the blade more than the other. In this case, chlorotic areas may appear orange or red due to the overlying anthocyanin pigments.
4. **Necrosis:** Necrotic lesions may develop in the chlorotic zones. These necroses spread as irregular patches until the leaf blade is entirely brown and dry.
5. **Effect on cell division and growth:** Phosphorus is a key molecular component of reproduction. When phosphorus is present in inadequate levels, genetic processes like cell division and plant growth become slow. Hence, phosphorus deficient plants may mature at a slower rate than plants with adequate amounts of phosphorus.
6. **Effect on storage of carbohydrates:** Phosphorus deficiency may also create an imbalance in the storage of carbohydrates. There may be excess carbohydrate within the plant. But they are in imbalance form. Thus these are not much helpful for plant. This carbohydrate buildup can be observed by darkening of leaves. In some plants, the leaf pigment change as a result of this process. It can turn leaves a dark purplish color.
7. **Increase in pith:** Deficiency of phosphorus causes bulky pith in stem.
8. **Non-woody slender stems:** In some cases, deficiency of phosphorus delays the maturity of plant. It produces non-woody slender stems.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Clay	Clay is an inorganic material. It consists of aluminium and silicon oxides.
Free space	The term free space is used for the part of the plant cell and tissue where ions can freely move by diffusion. It is also called apparent free space (AFS).
Mass flow	The movement of ions along with bulk amount of water is called mass flow of ions.

Ion exchange	The exchange of anions or cations of the cells with the ions of the same and equivalent charge of outer solution is called ion exchange.
Donnan equilibrium	The equilibrium of ions between root cells and soil solution in the presence of fixed ions in the root cells is called Donnan equilibrium.
Contansport	The transport by which a substance indirectly drives the active transport of several other solutes is called contransport.
Antiprot	In this case, the two transported molecules moves in opposite direction.
Symport	In this case, two molecules move in the same direction
Essential elements	The elements which are needed by the plants for normal and healthy life are called essential elements. Only 16 elements are essential elements.

MODEL SUBJECTIVE QUESTIONS

1. **How does soil act as source of minerals.**
2. **Describe different methods of passive absorption.**
3. **Describe different methods of active absorption.**
4. **Give physiological role and deficiency symptoms of Nitrogen.**
5. **Give physiological role and deficiency symptoms of Calcium.**
6. **Give physiological role and deficiency symptoms of potassium.**
7. **Give physiological role and deficiency symptoms of phosphorus.**

SHORT QUESTIONS

1. **What are Clay and humus?**

Ans: Clay is an inorganic material. It consists of aluminium and silicon oxides. Humus consists of carbonaceous residue. It is derived from lignin of cell walls.

2. **What is free space or apperent free space?**

Ans: The term **free space** is used for the part of the plant cell and tissue where ions can freely move by diffusion. It is also called **apparent free space (AFS).**

3. **What is ion exchange?**

Ans: **The exchange of anions or cations of the cells with the ions of the same and equivalent charge of outer solution is called ion exchange.**

4. **What is contact exchange theory?**

Ans: According to this theory, ions are not dissolved in water. The roots are present near the clay particles in the soil. Cations are adsorbed on surface of the clay colloids. The roots releases H^+ ion. These H^+ ion are directly exchanged by the cations of clay particles.

5. **What is carbonic exchange theory?**

Ans: According this theory, ions first dissolve in the soil solution. Carbon dioxide released during the respiration in roots. It dissolves in soil water and form carbonic acid (H_2CO_3). Carbonic acid is a weak acid. It dissociates into H^+ ions ad HCO_3^- ions. H^+ ion ions reach the clay particles. They are exchanged with cation like K^+ present in the soil.

6. **What is Donn equilibrium?**

Ans: The equilibrium of ions between root cells and soil solution in the presence of fixed ions in the root cells is called Donnan equilibrium.

7. **How does proton pump works?**

Ans: Proton pump is present in the membrane of the root cells. It is an electrogenic pump. It uses ATP. Proton pump actively transport hydrogen ion of the cell. It also creates membrane potential in the cells. It set proton gradient across the membrane of cell. This gradient enforces the minerals inside.

8. **What is contransport?**

Ans: The transport by which a substance indirectly drives the active transport of several other solutes is called contransport.

9. **Differentiate between antiport and symport.**

Ans: **Antiprot:** In this case, the two transported molecules moves in opposite direction.

Symport: In this case, two molecules move in the same direction

10. **What is meant by essential elements? Give their number**

Ans: The elements which are needed by the plants for normal and healthy life are called essential elements. Only 16 elements are essential elements.

11. **What are macronutrients?**

Ans: These elements are required by the plants in large quantity. The major elements are C, F, O, N, S, P, Ca, K and Mg.

12. **What are trace elements?**

Ans: The remaining 7 elements are required in small quantity. These are called trace micronutrients. The micronutrients are Fe, Mn, B, Cu, Zn, Mo and Cl.

13. **Give two physiological roles of nitrogen.**

Ans: Nitrogen is an essential component of proteins and nucleic acids.

It is also an important component of chlorophyll.

14. **Give two deficiency symptoms of nitrogen.**

Ans: The lateral buds remain dormant. Flower formation is delayed or suppressed. If flowers are formed, the fruits and seeds remain small and weak.

15. **Give two physiological roles of calcium.**

Ans: Calcium is deposited in the cell wall in the form of calcium pectate. Calcium pectate forms middle lamella. Cell wall remains weak without this compound. Calcium concentrates around the chromosomes. It plays role in binding of nucleic acid to protein.

16. **Give two deficiency symptoms of calcium.**

Ans: Chlorotic patches appear near the leaf margin in young leaves. Calcium deficiency causes rapid disintegration of the growing tips of roots and shoots in many plants.

17. **Give two physiological roles of potassium.**

Ans: It provides the necessary ionic balance. This ionic balance is necessary for the survival of plant. It plays an important role in the plant metabolism. It acts as an activator of many plant enzymes.

18. **Give two deficiency symptoms of phosphorus.**

Ans: Growth is retarded and leaf colour becomes dark-green. Sometimes dead patches appear on leaves, petioles and fruits and the leaves fall early.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. **Which of the followings forms colloids in soil?**

(a) Sodium (b) Potassium (c) Calcium (d) Nitrates

2. **The theory of active solute absorption was put forward by:**

(a) Hoagland (b) Dixon (c) Syere (d) None

substrate must correspond in size and shape to the active site on the enzyme. Then it produces the desired chemical response. Enzyme locates its appropriate substrate. Then the substrate enters the receptor site. Finally both the enzyme and substrate form a complete union. Now chemical reaction can occur.

4. **Inhibitors jam the lock:** Inhibitors work like a key. They can enter the keyhole (active site). But they cannot turn the lock. The inhibitors jam the active sites. Thus they cannot form product. They slow down or prevent the chemical reaction.

Induced Fit Model

This model was proposed by **Koshland** in 1959. He proposed this model on the basis of new evidences. He describes that when a substrate combines with an enzyme, it induces changes in the active site. These changes enable the enzyme to perform its catalytic activity. The induced-fit model is actually a part of an earlier **lock and key model**. It was proposed by Emil Fischer in 1894. The lock and key model states that the substrate acts as a key to the lock of the active site. The active site and substrate are exact matches for each other. It is similar to puzzle pieces fitting together. In this model, only a single substrate is the exact match for the enzyme. Once the enzyme finds its exact substrate, the chemical reaction begins.

The **induced-fit model** is considered more correct version. According to it, active site and the substrate are initially not perfect matches for each other. Rather, the substrate induces a change in shape in enzyme. Now enzyme becomes active. It changes the substrate into product. Induced fit model is like a **hand-in-glove model**. Here it may be difficult to insert the first finger into the proper place. But once done, the other fingers go in easily. The glove is now properly aligned.

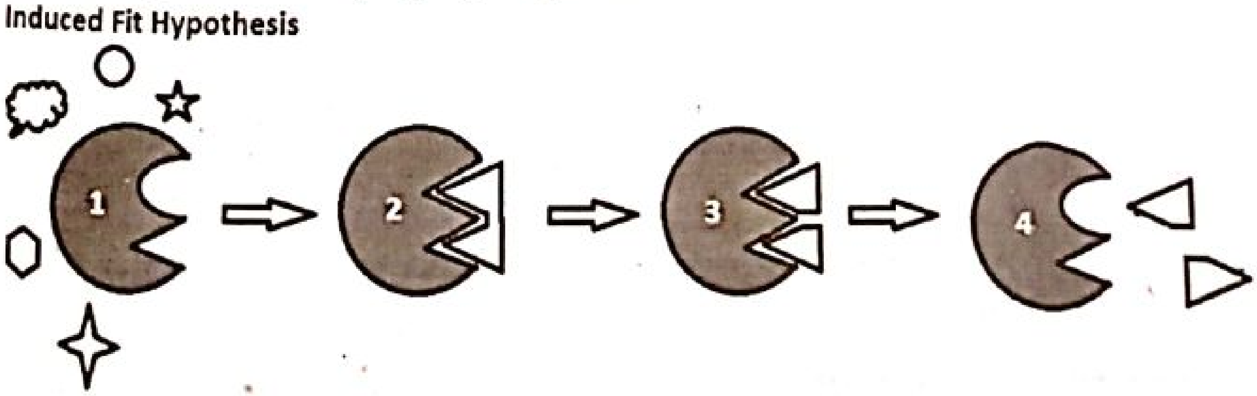


Fig: Induced fit model

CLASSIFICATION OF ENZYME

NOMENCLATURE OF ENZYME

Following roles are followed for the naming of enzymes:

1. All enzyme names end with the suffix **ase**. They are named after their substrate. For example urease acts upon urea. The sucrase acts upon sucrose.
2. They may be named on the nature of the reaction that they catalyze. For example, oxidase promotes oxidation with the help of molecular oxygen. Dehydrogenase catalyses the removal of hydrogen. Isomerase catalyses the transformation of a

molecule into its isomeric form.

3. But several digestive enzymes were discovered earlier. They do not follow this rule. For example, pepsin and trypsin.
4. Some enzymes are given a double name. One name is for the substrate and the other for the reaction that the substrate undergoes. For example alcohol dehydrogenase catalyses the dehydrogenation of ethyl alcohol and pyruvic carboxylase catalyses the removal of carbon dioxide from the carboxyl group of pyruvic acid.

IUB Classification of Enzymes

- **Enzymes are classified according to the reaction they catalyze.**

Class	**Reactions catalyzed**
• **Oxidoreductases**	**Oxidation-reduction**
• **Transferases**	**Transfer groups of atoms**
• **Hydrolases**	**Hydrolysis**
• **Lyases**	**Add atoms/remove atoms to/from a double bond**
• **Isomerases**	**Rearrange atoms**
• **Ligases**	**Use ATP to combine molecules**

CLASSIFICATION OF ENZYMES

The **International Union of Biochemists** set up a **Commission on Enzymes.** This commission divides the enzymes into six major groups on the basis of the biological reactions they catalyze. These are divided into subclasses and further subclasses. There are following six major groups of enzymes.

1. **Oxidoreductases**

These enzymes catalyze biological oxidations and reductions. They are further subdivided into oxidases, peroxidases, catalases, dehydrogenases and reductase. For example, nitrate reductase catalyses the reduction of nitrate into nitrite in the presence of the coenzyme NADH.

2. **Transferases:** These enzymes catalyze the transfer of a group from one kind of molecule to another. They are subdivided into the following subclasses according to the group transferred.

Enzyme	**Name of the chemical group transferred**
Transphosphorylases	Phosphate
Transpeptidases	Amide, amino acid
Transarninases	Amino
Transmethylases	Methyl

3. **Hydrolases:** These enzymes catalyses the hydrolysis of the molecules of organic foods, polysaccharides, fats and proteins. In the process the large food molecules are split into smaller fragments by the addition of water. Thus these enzymes are also called digestive or hydrolytic enzymes. This group includes following enzymes:

(i) **Diastase:** They hydrolyze starch into glucose. It occurs in germinating seeds, leaves and storage organs. The component enzymes of "**diastase system**" are amylase, maltase and dextrinases. Amylase occurs in two forms α-amylase and β-amylase. Both these enzymes hydrolyse starch to smaller units called dextrins. Amylase hydrolyses the amylose fraction maltose.

(ii) **Maltase:** It hydrolyses maltose into two molecules of glucose.

(iii) **Sucrase:** It hydrolyses sucrose (cane-sugar) into glucose and fructose.

(iv) **Lipase:** It hydrolyses fats into fatty acids and glycerol. It is present in oil seeds like castor bean.

(v) **Phosphorylase:** It catalyses the reversible splitting of carbohydrates with the help of phosphoric acid.

(vi) **Phosphatase:** It catalyses the removal of phosphoric acid (P) from esters of phosphoric acid.

4. **Lyases or addition enzyme:** These enzymes remove or add group from or to a double bond of an organic molecule. The names of subclasses are given on the basis of group removed or added. Its examples are hydrases (water), carboxylases (CO_2) and aminases (ammonia).

5. **Isomerases:** They change organic molecule into its isomeric form. These include isomerases, epimerases and mutases:

   (i) **Isomerases:** They catalyze the reversible isomerization of aldose and ketose sugars. Their examples are phosphotriose isomerase and phosphohexose isomerase.

   (ii) **Epimerases:** They cause structural change in the molecule of a sugar or its derivative. Thus two forms of molecules are formed. These forms are called **epimers**. Its example is phosphoketopentose epimerase.

   (iii) **Mutases:** They shift the position of a group within a molecule. An example of mutase is phosphoglyceromutase.

6. **Ligases:** These enzymes link two molecules along with the breakdown of a pyrophosphate bond (PP) of ATP. They are also called **synthetases**. These enzymes catalyze the:

   (i) Joining of amino acids to RNA molecules.

   (ii) The synthesis of the amide asparagines by joining aspartic acid and ammonia.

   (iii) The synthesis of fattyacyl CoA complex from fatty acids and Co-A in the synthesis of fats.

   (iv) The joining of amino acids by peptide bonds to form polypeptides

   (v) The synthesis of citric acid by the linking of the acetyl group of acetyl-CoA to oxaloacetic acid.

PROPERTIES OF ENZYMES

There are following properties of enzymes.

1. Globular proteins

Most of enzymes are globular protein. A few enzymes like **ribozymes** are nucleic acid in nature. Globular protein of enzymes have tertiary configuration. Globular structure is very important for proper functioning of enzyme.

2. Catalytic Properties

Enzymes influence the speed of chemical reactions. They are not utilized or consumed in the chemical reaction. So they do not appear in the end products of the reaction. An enzyme cannot start the reaction. It can only speed up the reaction. A very small quantity of the enzyme can catalyze a large quantity of the substrate and at a great speed. The effectiveness of an enzymatic reaction is expressed in form of turnover number. **The number of substrate molecules on which one enzyme molecule acts in one second is called turnover over number.** The number for sucrose is 10^5 and for catalases 10^6.

3. Lowering the Activation of Reaction

Activation energy is the minimum energy that is required to start a reaction. Enzyme lowers the activation of energy. The reaction can take place in the absence of enzyme. But it needs higher amount of activation energy.

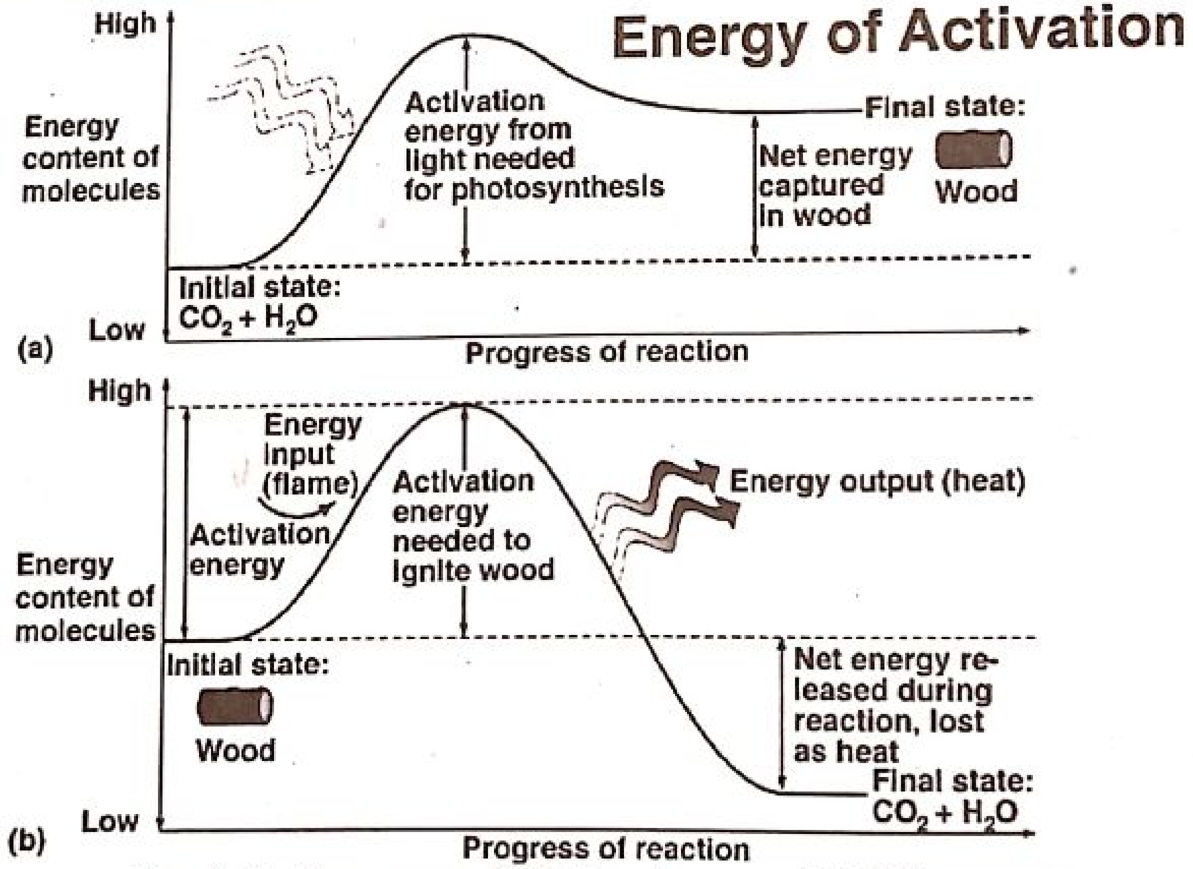

Energy of Activation
(a)
High
Low
Energy content of molecules
Activation energy from light needed for photosynthesis
Final state:
Net energy captured in wood
Wood
Initial state: $CO_2 + H_2O$
Progress of reaction
(b)
High
Low
Energy content of molecules
Energy input (flame)
Activation energy
Activation energy needed to ignite wood
Energy output (heat)
Initial state:
Wood
Net energy released during reaction, lost as heat
Final state: $CO_2 + H_2O$
Progress of reaction

Fig: Activation energy (a) Without enzyme (b) With enzyme

4. Specificity of Enzyme Action

Enzymes are specific in their action. The specificity of enzymes is due to their primary amino acid sequence. A given enzyme can act only on a particular substrate or a particular group of substrates. An enzyme is thus specific for both the substrate and the type of reaction that it catalyses. Thus, sucrase acts upon sucrose (cane-sugar) and lactase on milk-sugar (lactose) Sucrase will not act upon other sugars.

5. Reversibility of Enzyme Action

The majority of reactions catalyzed by enzymes are reversible. Thus an enzyme can speed up a reaction in both directions. Thus the system attains a state of equilibrium in a short time. In the guard cells of the stomata the enzyme starch phosphorylase converts starch and inorganic phosphate into glucose monophosphate. The reaction is reversible. The same enzyme converts glucose monophosphate into starch and inorganic phosphate. The direction of the reaction depends upon several factors. It depends on pH and chemical potential of both the reactants. When the chemical potential of the products is less than that of the reactants then the reaction takes place only in one direction.

Synthesis of starch, proteins and fats are unidirectional irreversible enzymatic reactions. Such reactions have two different sets of enzymes. One enzyme is used for the synthesis of these compounds and the other is used for their breakdown.

6. Product Inhibition

The accumulation of products of the reaction can inhibit the enzymatic activity. The effect is very important for cell. It is a self regulating mechanism of reaction rates. It maintains the concentration of the product in a cell at a suitable level.

7. Allosterism

Some enzymes have specific allosteric site for binding of certain effectors. It is called allosteric site. The binding of effector causes change in the structure of enzyme. This phenomenon is called Allosterism. Allosterism is shown by many enzymes.

8. Sensitivity of Enzymes

Enzymes are sensitive to following factors

(i) **High temperature:** Enzymes are sensitive to heat. The activity of enzymes increases with the increase of temperature up to 50°C. There is initial rise in the activity of enzymes above this temperature. But this is soon followed by a decline in activity. The enzymes are denatured at 70—100°C. Some enzyme can withstand temperature of 100—120°C for long periods in dry conditions. Such conditions are present in spores and dry seeds.

(ii) **Low temperature:** Enzymes are also sensitive to low temperatures. They are inactivated but not destroyed at 0°C or below.

(iii) **Radiations:** Enzymes are also destroyed by radiations of lower wavelengths such as ultraviolet rays and X-rays.

(iv) **pH:** Each enzyme has an optimal pH. Its activity slows down with an decrease or increase in the pH. Generally, catalases show optimum activity in a neutral medium. Amylose acts best in neutral or slightly acidic medium. Sucrase and lipase act in acid medium and trypsin act in alkaline medium.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Enzyme	An enzyme is a biological catalyst that can accelerate a specific chemical reaction by lowering the activation energy but remain

	unaltered in the process.
Key and lock model	According to this model a specific enzyme can transform only specific substrate into products.
Cofactors	The metal ions which are loosely attached with the enzymes are called cofactors.
Cofactors	Coenzymes are non protein, organic molecules that participate in enzyme-catalyzed reactions.
Prosthetic group	The covalently bonded non-protein part cofactors are called prosthetic group.
Oxidoreductase	These enzymes catalyze biological oxidations and reductions.
Transferase	These enzymes catalyze the transfer of a group from one kind of molecule to another.
Turnover number of enzyme	The number of substrate molecules on which one enzyme molecule acts in one second is called turnover over number.
Activation energy	Activation energy is the minimum energy that is required to start a reaction.

MODEL SUBJECTIVE QUESTIONS

1. **What are enzymes? Discuss their nature.**
2. **Write note on cofactors and coenzymes.**
3. **Give classification and nomenclature of enzymes.**
4. **Describe properties of enzymes.**

SHORT QUESTIONS

1. **Define enzymes.**

Ans: An enzyme is a biological catalyst that can accelerate a specific chemical reaction by lowering the activation energy but remain unaltered in the process.

2. **What is the chemical nature of enzyme?**

Ans: Most enzymes are proteins. Some are nucleic acids (RNA) like **ribozymes**.

5. **What is active site of enzyme? Give its function.**

Ans: The globular structure of enzyme has at least one surface region. This region has a crevice or pocket. This crevice occupies only a small portion of the surface of enzymes. It is known as the enzyme's **active site**. Active site has a specific shape. Therefore, a substrate molecule fits into it in a very specific way.

4. **What are the components of active site?**

Ans: The active site has two components: **Binding site:** It recognizes the specific substrate and forms enzyme substrate complex. This reaction activates the catalytic site. **Catalytic site:** The activated catalytic site changes the substrate into products.

6. **What is key and lock model?**

Ans: **Emil Fischer** proposed the lock and key model in 1890. According to this model a specific enzyme can transform only specific substrate into products. According to this model, the active site is a rigid structure. It cannot be changed during any step of the reaction.

7. What is induced fit model? Give its significance.

Ans: This model was proposed by **Koshland** in 1959. He proposed this model on the basis of new evidences. He describes that when a substrate combines with an enzyme, it induces changes in the active site. These changes enable the enzyme to perform its catalytic activity.

7. What are cofactors? Give examples.

Ans: The metal ions which are loosely attached with the enzymes are called cofactors. These metal ions are Ca^{-2}, Mg^{-2}, Mn^{-2}, Cu^{-2}, and Zn^{-2}.

8. Differentiate between coenzyme and prosthetic groups.

Ans: Coenzymes are non protein, organic molecules that participate in enzyme-catalyzed reactions. The covalently bonded non-protein part cofactors are called prosthetic group.

9. What is allosteric site? Give its function.

Ans: Some enzymes have special allosteric site. Some specific effectors can bind with this allosteric site. Allosteric enzymes change their structure in response to binding of effectors.

10. Differentiate between apoenzyme and holoenzyme.

Ans: Some enzymes require prosthetic group for their normal activities. Prosthetic group is firmly bound to the enzyme. It activates the enzyme. The inactive enzyme without prosthetic group is called apoenzyme. The active enzyme with attached prosthetic group is called holoenzyme.

11. What are Oxidoreductases? Give examples.

Ans: These enzymes catalyze biological oxidations and reductions. They are further subdivided into oxidases, peroxidases, catalases, dehydrogenases and reductase.

12. What are Hydrolases? Give two examples.

Ans: These enzymes catalyses the hydrolysis of the molecules of organic foods, polysaccharides, fats and proteins. In the process the large food molecules are split into smaller fragments by the addition of water. Thus these enzymes are also called digestive or hydrolytic enzymes. Examples: Maltase, pepsin

13. What is activation energy? How is it lowered?

Ans: Activation energy is the minimum energy that is required to start a reaction. Enzyme lowers the activation of energy. The reaction can take place in the absence of enzyme. But it needs higher amount of activation energy.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. Which of the followings enzymes is not protein?

(a) Diastase (b) Pepsin (c) Ribozymes (d) Trypsin

2. Key and lock model was proposed by:

(a) Koshland (b) Dixon (c) Fisher (d) None

3. Induced fit model was proposed by:

(a) Koshland (b) Dixon (c) Fisher (d) None

4. The metal ions which are loosely attached with the enzymes are called:

(a) Coenzyme (b) Prosthetic groups (c) Cofactors (d) None

5. The non protein, organic molecules that participate in enzyme-catalyzed reactions is:

(a) Coenzyme (b) Prosthetic groups (c) Cofactors (d) None

6. The covalently bonded non-protein part cofactors are called prosthetic group.

(a) Coenzyme (b) Prosthetic groups (c) Cofactors (d) None

7. NAD is:

(a) Coenzyme (b) Prosthetic groups (c) Cofactors (d) None

8. Which of the followings is hydrolyze enzyme?

(a) Ribozyme (b) Diastase (c) Hydrase (d) Mutase

Answers: 1. (c) 2. (c) 3. (a) 4. (c) 5. (a) 6. (b) 7. (a) 8. (b)

Fill in blanks

1. Most enzymes are proteins. Some are nucleic acids (RNA) like __________.
2. _________ proposed the lock and key model in 1890.
3. The metal ions which are loosely attached with the enzymes are called _________.
4. _________ are non protein, organic molecules that participate in enzyme-catalyzed reactions.
5. The covalently bonded non-protein part cofactors are called ________ group.
6. _________ enzymes change their structure in response to binding of effectors.
7. The inactive enzyme without prosthetic group is called _______.
8. The active enzyme with attached prosthetic group is called __________.
9. Sucrase and lipase act in acid medium and trypsin act in _________medium.
10. Maltase hydrolyses maltose into two molecules of ______ .
11. The International Union of _________set up a Commission on Enzymes.
12. Amylose acts best in neutral or slightly _________ medium.
13. Enzymes work like a _________ in the chemical reaction process.

Ans 1. Ribozymes 2. Fischer 3. Cofactors 4. Coenzymes 5. prosthetic 6. Allosteric 7. apoenzyme 8. Holoenzyme 9. alkaline 10. Glucose 11. Biochemists 12. acidic 13. lock

True/False

1. Some are nucleic acids (RNA) like ribozymes.
2. Koshland proposed the lock and key model in 1890. According to this model a
3. The metal ions which are loosely attached with the enzymes are called coenzyme.
4. Allosteric enzymes change their structure in response to binding of effectors.
5. The inactive enzyme without prosthetic group is called Holoenzyme.
6. Enzymes work like a lock in the chemical reaction process.
7. The induced-fit model is actually a part of an earlier lock and key model.
8. Catalases enzymes catalyze the transfer of a group from one kind of molecule to another.
9. Activation energy is the minimum energy that is required to start a reaction.
10. The accumulation of products of the reaction can inhibit the enzymatic activity.
11. Catalases show optimum activity in a acidic medium.
12. Amylose acts best in neutral or slightly acidic medium.
13. Sucrase and lipase act in alkaline medium.
14. Maltase hydrolyses maltose into two molecules of glucose.
15. The International Union of Biochemists set up a Commission on Enzymes.

Answers: 1. T 2. F. Emil Fischer 3. Cofactors 4. T 5. 6. F. Apoenzyme 7. T 8. F Transferases 9. T 10. T 11. F. neutral 12. T 13. F. acid 14. T 15. T

Chapter 5

PHOTOSYNTHESIS

Syllabus
1. The process of photosynthesis
2. Absorption and action spectra.
3. Mechanism: Light reactions (electron transport chain and photophosphorylation) and dark reaction (Calvin cycle).
4. Factors affecting photosynthesis: Concept of limiting factors
5. Product of photosynthesis.

PROCESS OF PHOTOSYNTHESIS

Photosynthesis (photo-light, synthesis-putting together) may be defined as the process in which the green plants synthesize carbohydrates from carbon dioxide and water, using the energy of sunlight.

$$6CO_2 + 6H_2O \xrightarrow{\text{673 K cal of light energy}} C_6H_{12}O_6 + 6O_2$$

The raw materials for photosynthesis are water and carbon dioxide. Simple carbohydrates like glucose are formed from these inorganic raw materials. The molecules of water and carbon dioxide are broken down in this process. Their atoms are recombined into a new compound. The energy content of the end products is greater than the raw materials in this reaction. Thus energy must be supplied from outside. This energy is supplied by sunlight. This radiant energy of the sun is stored in the form of chemical energy. This process occurs only in cells which contain the green pigment chlorophyll.

673 K calories per mole is the total measurable energy change of the reaction. It can be made to do some work. There is also some (13 K cal) non-measurable energy change. The sum of the two is called the **free energy change of the reaction**. Its amount is 686 k calories.

(a) Raw materials of photosynthesis

The raw materials in this process are water and carbon dioxide. Water is absorbed by the roots from the soil in the vascular plants. It is transported up to the photosynthetic organs through the xylem. The carbon dioxide is absorbed by the aerial parts of the plants from the atmosphere.

(b) Products of Photcsynthesis

The products of photosynthesis in green plants are a simple carbohydrate like sugar and oxygen. The oxygen is released into the atmosphere in gaseous form. It is utilized by the animals and plants during respiration. Oxygen is a byproduct of photosynthesis. The more important product of photosynthesis is sugar. Sugar is the fundamental material. It is the starter point. More complex foods are formed from it. A part of this sugar is converted into complex carbohydrates like starch. A portion is also converted into oils. A part is used for the synthesis of proteins and other complex organic compounds.

Photosynthesis is the ultimate source of numerous plant products other than food. Some of these compounds are cellulose, rubber, plastics, alcohol, resin, oils and drugs.

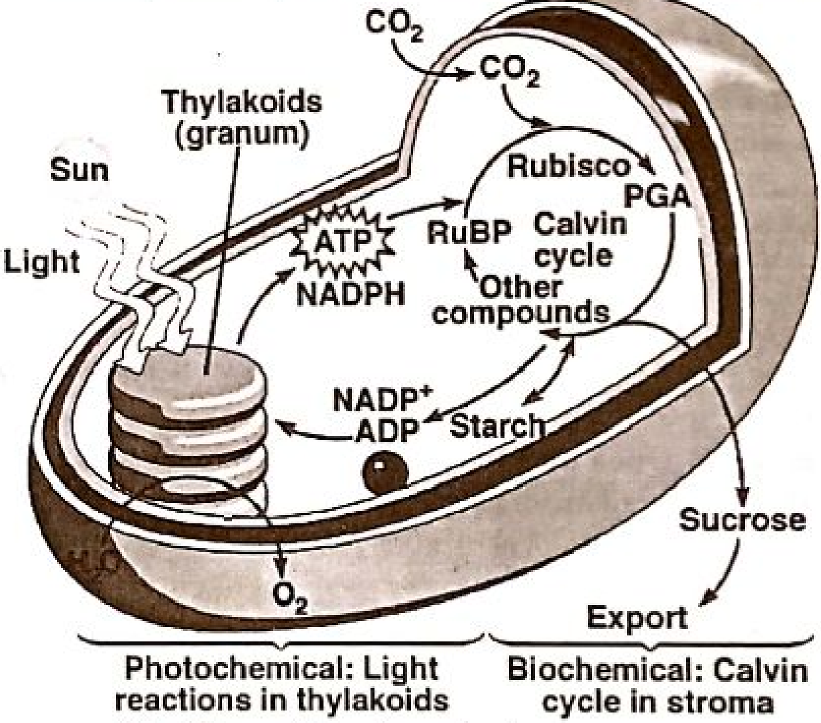


Fig: Steps of photosynthesis

(c) Energy

Photosynthesis utilizes the sun's energy. It takes place only during the sunlight. Photosynthesis converts radiant energy into chemical energy. Plants and animals use this energy of food for their growth, locomotion and other metabolic activities. The foods are oxidized and release energy. Thus all other animals and man depend on the sun energy stored by the plants.

(d) Steps of photosynthesis

Photosynthesis is divided into two steps:

(i) **Photochemical reaction or light reaction:** In this reaction light is trapped by the thylakoid of the granum. This light energy is used to synthesize NADPH and ATP. Both these products are used during biochemical reactions.

(ii) **Biochemical reaction or dark reaction (Calvin reaction):** This reaction takes place in the stroma of chlorophyll. Carbohydrates are synthesized during this reaction.

ABSORPTION AND ACTION SPECTRA

Light is electromagnetic energy. Electrochemical energy travels in the form of waves.

The distance between the crest of the electromagnetic waves is called wavelength. The entire range of radiations is known as **electromagnetic spectrum.** This spectrum includes wavelength of less than a nanometer to more than a kilo meter. The narrow band of wavelength from 380 to 750nm of electromagnetic spectrum is most important for life. It is called **visible spectrum**. Its various colours are detected by human eye. The visible spectrum includes red, orange, yellow, green, blue and violet.

Light travels in the form of photons. The energy of photon is related to its wavelength. Shorter the wavelength greater is the energy. The radiations that derive energy are blue and red. These wavelengths are most effectively absorbed by the chlorophyll.

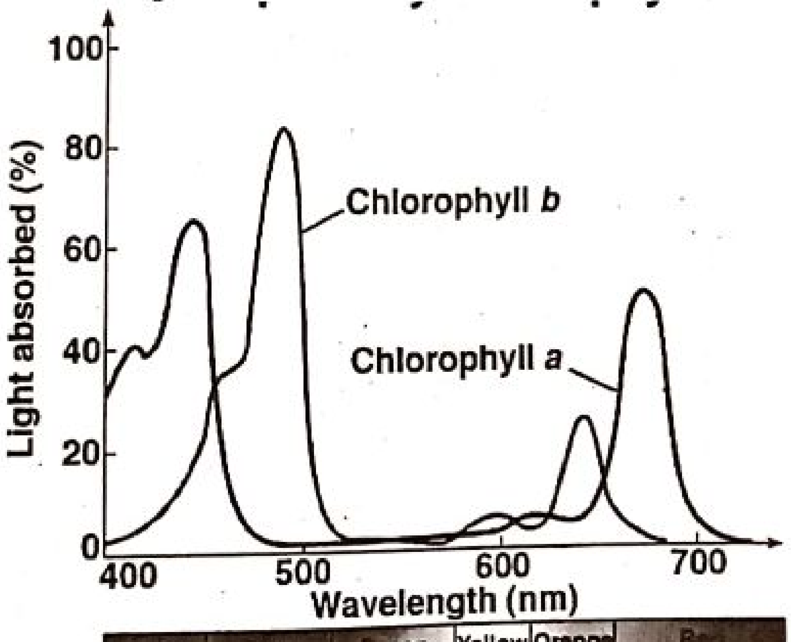
(A) Absorption Spectra

A plot (graph) showing absorption of light of different wavelength by a pigment is called absorption spectrum. A solution of a pigment is placed in a **spectrometer**. It gives the wavelength absorbed by the pigment. The light absorbed by the pigment is plot against wavelength. It gives absorption spectrum.

a) Both chlorophyll a and b show maximum absorption in the **blue- violet** and **orange-red** region of visible spectrum. Green and yellow light is absorbed very little. The blue and red light are used by the green plants as energy source for photosynthesis. The absorption of chlorophyll a shows two peaks at about 680 and 700 nm.

b) Carotenoids absorb radiant energy between 449 and 490 nm. Carotenes show absorption peaks at 449 and 478 nm.

c) The xanthophylls shows peak at 440 and 490 nm.



Absorption spectra of chlorophylls *a* and *b*.

(B) Action Spectra

The plot showing relative effectiveness of different wavelengths of light in photosynthesis is called action spectrum. Action spectrum identifies the pigments actually involved in the photosynthesis. The two photo system was also discovered by action spectrum. The action spectra are measured by spectrographs. A sample is placed in larger area of room. Monochromatic light is passed through it. Then its action is noted by spectrograph.

Measurement of first action spectrum

T. W. Engelmann measured the first action spectra. He dispersed sun light into seven colours with the help of prism. He allowed this disperse light fall on filament of spirogyra. Photosynthesis took place in spirogyra and it releases oxygen. He introduced aerobic bacteria into the system. The bacteria accumulated in the regions of filament that evolved the larger amount of oxygen. These regions were blue light and red light.

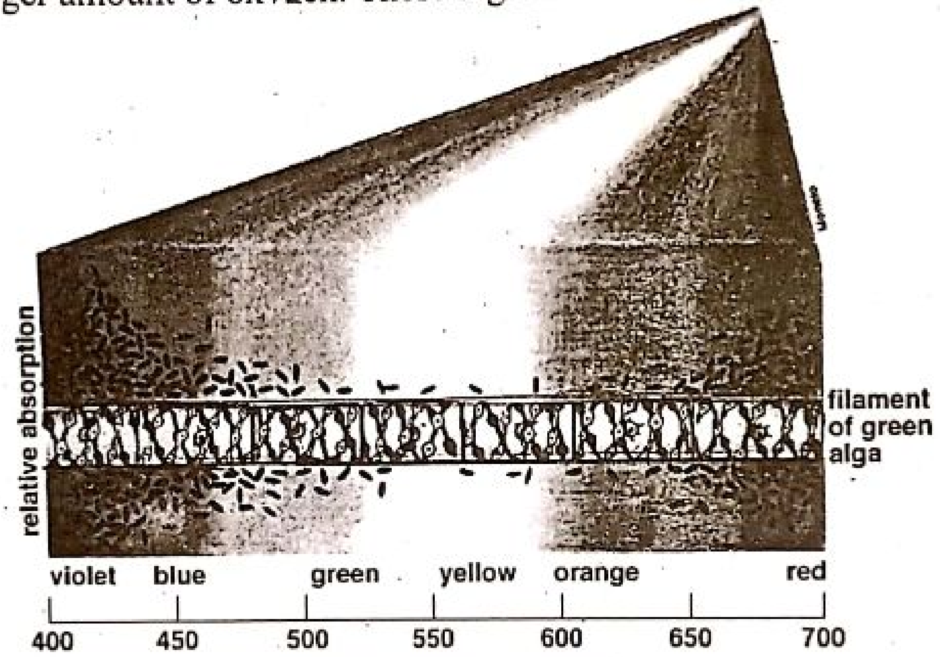
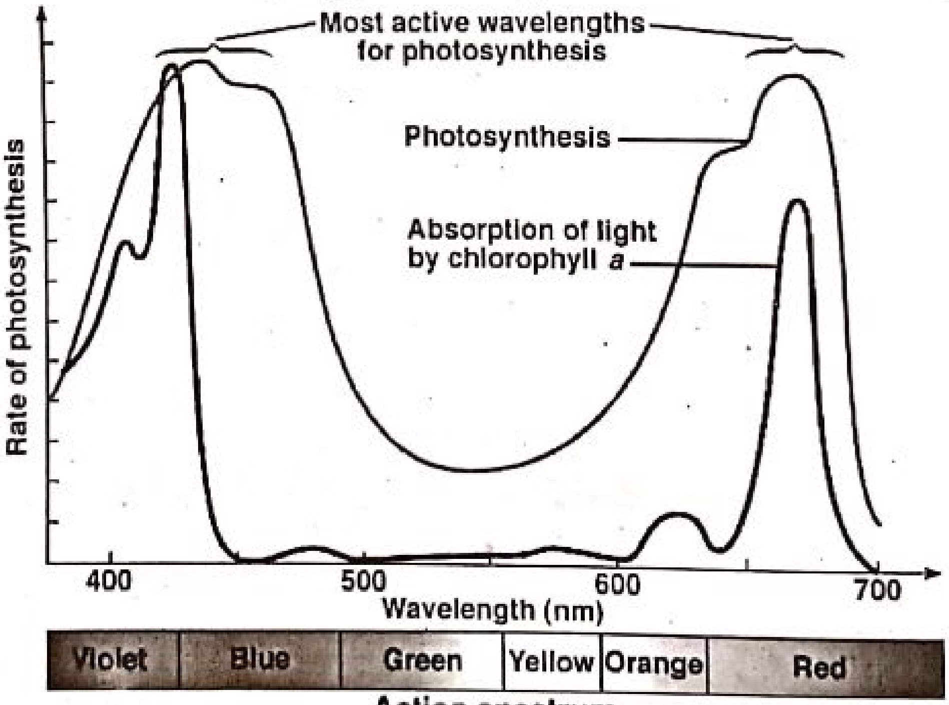


Fig: Engelmann's experiment



Action spectrum

Fig: Comparison of action spectrum and absorption spectrum

Comparison of absorption spectrum and action spectrum

Absorption spectrum is given by all the pigments (Chl a, b, carotene and xanthophylls). But the action spectrum is given by only chlorophyll a. It means chlorophyll a forms the reaction centre. There is a great difference between the absorption spectrum and action spectrum of chlorophyll a. The peaks of its action spectrum have more height and it valleys are much narrow than the absorption spectrum. It indicates that all other pigments are accessory. They transfer their energy to chlorophyll a. So it performs more photosynthesis than it actually absorbs light. Therefore, its action spectrum looks more efficient than the absorption spectrum.

MECHANISM OF PHOTOSYNTHESIS

LIGHT DEPENDENT OR LIGHT REACTION

PHOTOSYSTEMS

Photosynthetic pigments are organized into clusters called photosystems. These photosystems absorb and utilize the solar energy efficiently in the thylakoid membranes. Each photosystem is composed of two parts.

1. **Antenna complex or Light harvesting complexes.** Antenna complex is a light gathering part. It is composed of many molecules of chlorophyll a chlorophyll b and carotenoids. Light energy absorbed by the antenna complex is transferred to reaction centre. The antenna system of PSI is called **LHC I** and the antenna system of PSII is called **LHC II**.
2. **Reaction centre:** Reaction centre converts the light energy into chemical energy. It has one or more molecules of **chlorophyll a.** Chlorophyll a molecule of reaction centre and other associated proteins are closely linked to nearby primary electron acceptor and electron transport system. These associated parts are:
    - (i) **Primary electron acceptor:** It is associated with the reaction centre. It traps the high energy electron form the reaction centre. It then passes this electron to the series of electron carriers.
    - (ii) **Electron Transport chain:** It is associated with chlorophyll a molecule. Electron transport chain plays an important role in synthesis of ATP by chemiosmosis.

Types of photosystems

There are two types of photosystems, photosystem I (PS I) and photosystem II (PS II). They are named due to their order of discovery.

1. **Photosystem I:** It has chlorophyll a molecules. It absorbs maximum light of **700nm.** So it is called **P_{700}.** It contains chlorophyll a, chlorophyll b and carotene molecules. It is located in the **stroma thylakoids**. Two Fe-S proteins are also present in it. P_{700} is primary electron donor. The Fe-S accepts these electrons. Thus they act primary electron acceptor.
2. **Photosystem II:** It has chlorophyll a molecules in its reaction centre. It contains 200 molecules of chlorophyll a, b and 50 molecules of carotenes. This chlorophyll absorbs

best the light of **680nm**. So this chlorophyll is called **P_{680}**. It is located in the **grana thylakoids.** PSII is both electron donor and electron acceptor.

a) **Pheophytin and associated quinine (Q):** They act as electron acceptor.

b) **Manganese protein:** These proteins contain four Mn^{+2} ions. It acts as electron donor.

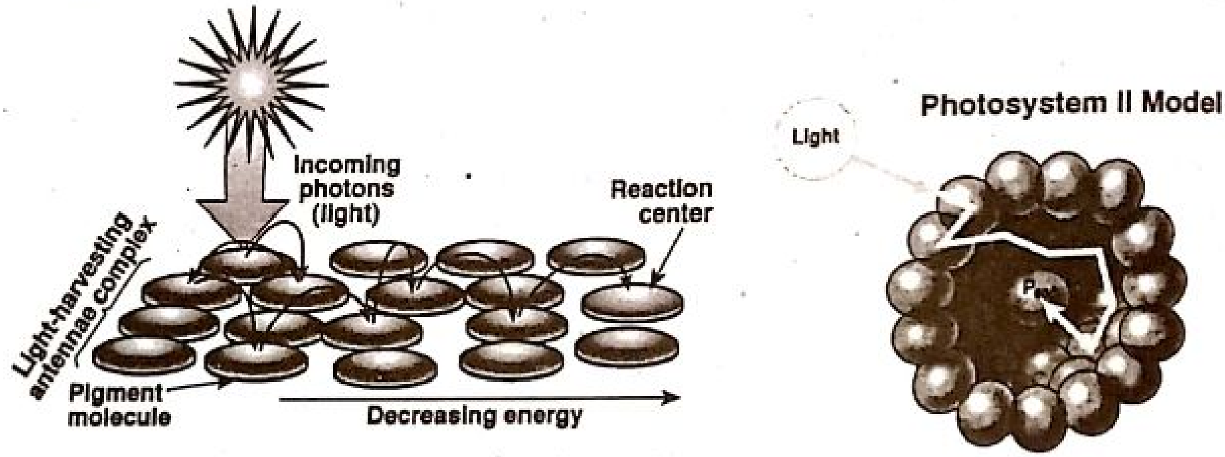


Fig: Photosystems

LIGHT REACTION OR PHOTOCHEMICAL PHASE OR HILL'S REACTION

The process in which $NADPH_2$ and ATP are formed in the presences of light is called light reaction or photochemical phase of photosynthesis. It was studied by Robert Hill. So it is also called **Hill's reaction**. There are two types of electron transformation during light reactions.

1. Non –cyclic electron flow (non-cyclic phosphorylation)
2. Cyclic electron flow (cyclic phosphorylation)

NON-CYCLIC PHOSPHORYLATION

Non –cyclic electron flow (Z-Scheme)

The formation of ATP during non-cyclic flow is called non-cyclic phosphorylation. In this case, the electron passes through two photosystems. It is most common type of electron flow. The path of electron through the two photosystems during non-cyclic photophosphorylation is called **Z- scheme**. It forms Z-shape path.

1. **Excitation of electron at PS II:** Photosystem II absorbs light. An electron is exited to a higher energy level in the reaction centre of the chlorophyll P_{680}. This electron is captured by the **pheophytin** (primary electron acceptor of PS II). The P680 becomes positively charged. It attracts electron from the Mn-protein. Mn-protein becomes oxidized and it acts as strong reducing agent.
2. **Photolysis of water: The splitting of water and release of oxygen during photosynthesis is called photolysis.** This reaction splits the water molecules into two hydrogen ions and an oxygen atom. Mn-protein attracts electrons from water. The oxygen atom combines with another oxygen atom to form O_2. It is by product of the

photosynthesis.

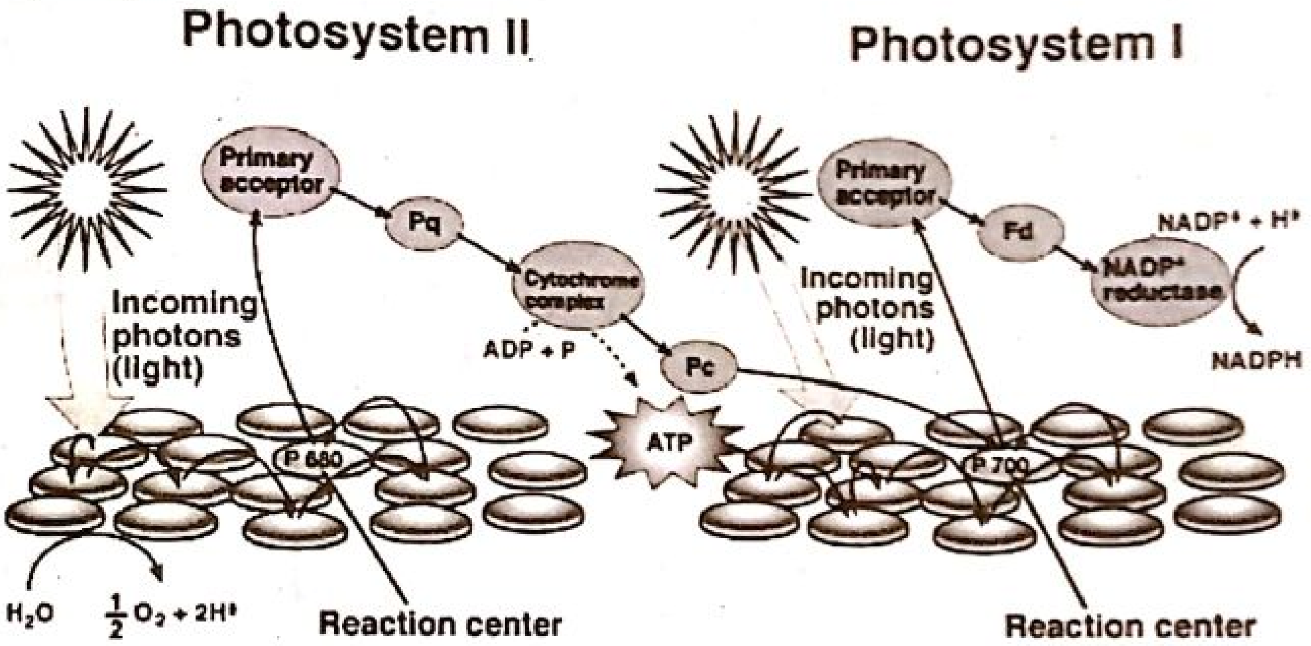
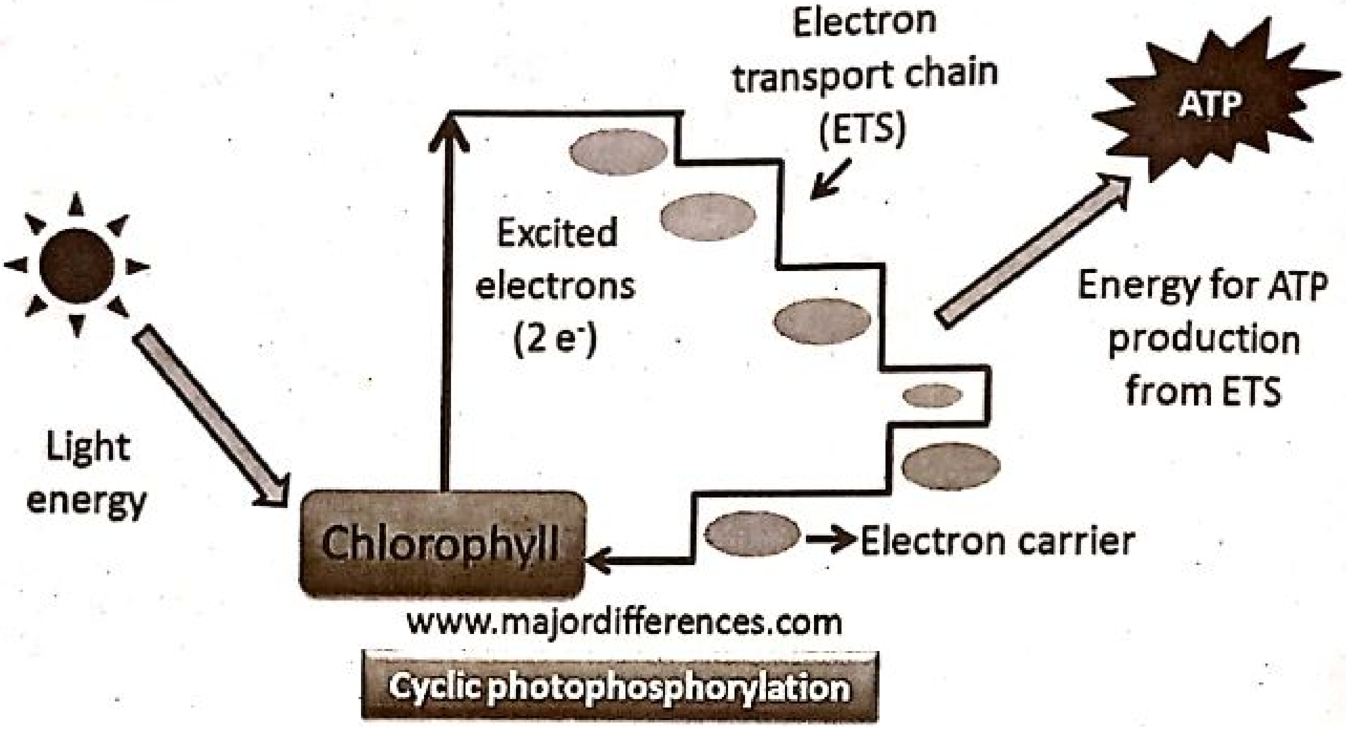


Fig: Light reaction

3. **Electron transport chain (ETC):** Each photoexcited electron passes from the pheophytin (primary electron acceptor) of the photosystem II to photosystem I through an electron transport chain. This electron transport chain has following electron carriers:
   a) **Plastoquinone (PQ):** Electrons are accepted by PQ and it reduces to form PQH_2. This reduction requires two electron and two protons (H^+). These protons are absorbed from stroma side of the membrane. The PQH_2 donates electrons to cytochromes and again become PQ. The two protons remain in the thylakoids. They reduce the pH there. Low pH helps in the photophosphorylation.
   b) **A complex of two Cytochromes:** It is composed of two cytochromes b_6 (Fe-S protein) and cytochrome f.
   c) **Plastocyanin (PC):** It is a copper containing protein. It finally donates electron to PSI.
4. **Photophosphorylation: The synthesis of ATP due to light energy is called photophosphorylation.** As the electrons move down the chain, their energy goes on decreasing. This energy is used by the thylakoid membranes to synthesize ATP. The thylakoid have **ATP synthase complex**. ATP is synthesized during chemiosmosis. This ATP will be used during synthesis of sugar in the **Calvin cycle** (dark reaction).
5. **Photosystem I:** The P_{700} chlorophyll of Photosystem I absorb light energy. It drives its electrons to the Fe- S protein (primary acceptor of the photosystem I). It creates a hole in the molecule of P_{700}.

   The electrons of the photosystem II reaches the bottom of the electron transport chain and fill the electron hole in Chlorophyll P_{700} molecule of photosystem I.
6. **Synthesis of $NADPH_2$:** Fe – S protein transfer the electrons to **ferredoxin (Fd)**. The

Fd is an iron containing protein. An enzyme **NADP reductase** transfers the electrons from Fd to **NADP**. This is the redox reaction. It stores the high-energy electrons in $NADPH_2$. The $NADPH_2$ molecule will provide reducing power for the synthesis of sugar in the Calvin cycle.



Cyclic photophosphorylation

CYCLIC PHOSPHORYLATION (CYCLIC ELECTRON FLOW)

The returning back of the same excited electrons to the excited chlorophyll by producing a molecule of ATP it is called cyclic phosphorylation. It is a less common type of electron flow. In this case, only photosystem I is involved. The photoexcited electrons take an alternative path. It does not use photosystem II.

This cycle may take place when there is less amount of ATP for Calvin Cycle. It slows down the cycle. Therefore, the NADPH accumulates in the chloroplast. This rise in NADPH may simulate the temporary shifting from non-cyclic to cyclic electron flow. The cyclic electron flow continues until the demand of ATP fulfilled. Therefore, the cyclic flow is a short circuit. Following steps take place during cyclic phosphorylation:

1. P_{700} of the photosystem 1 absorbs light. This light energy drive electrons form P_{700} of the photosystem I to primary electron acceptor. It produces electron hole in the chlorophyll.
2. The primary electron acceptor of photosystem I transfers the photoexcited electrons to Fe –S protein.
3. Fe – S protein transfer the electron to ferredoxin (Fd).
4. The electrons are transferred from **ferredoxin (Fd)** to **Cytochromes complex (ETC)**.
5. Finally, the Cytochromes complex returns these electrons to exited chlorophylls of the P_{700}. A molecule of ATP is produced during this transfer of electrons through ETC by chemiosmosis. The NADPH is not produced and oxygen is also not released.

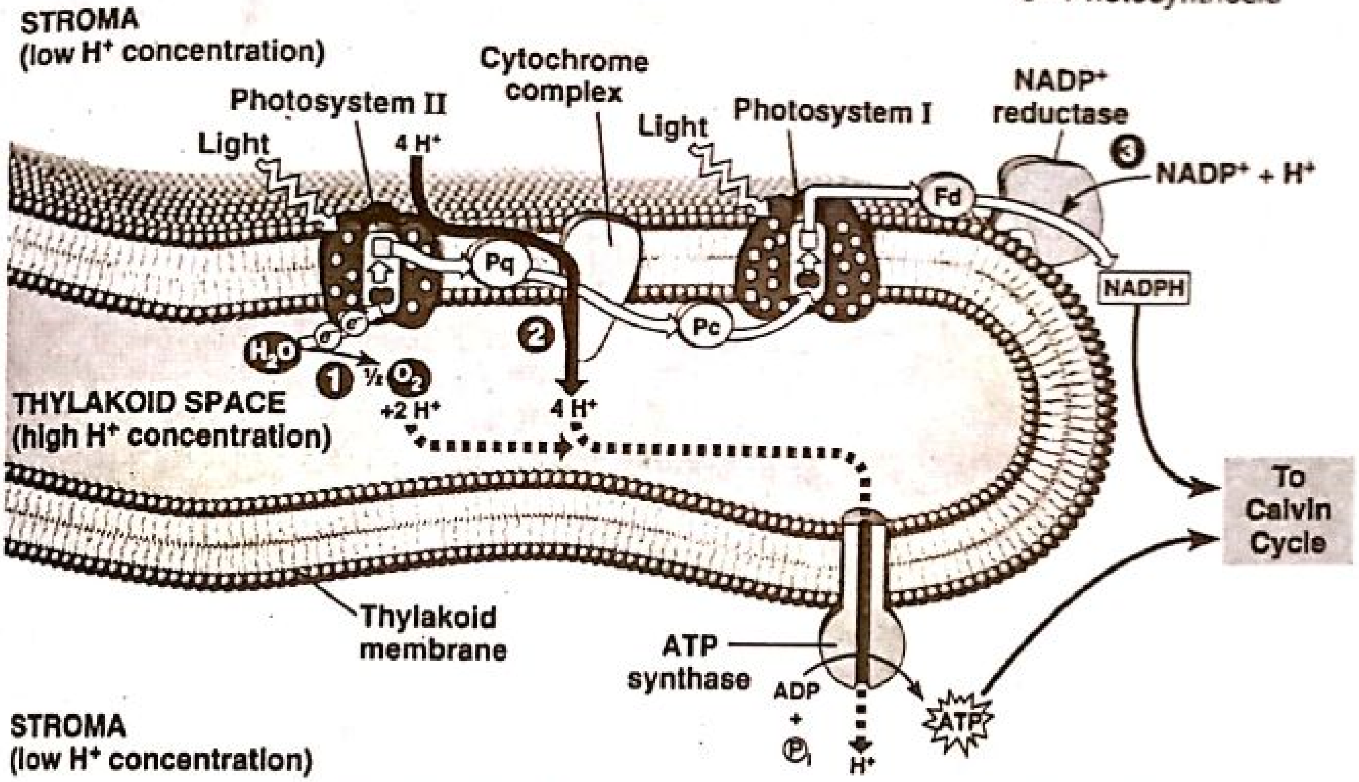


Fig: Electron transport chain and chemiosmosis in thylakoids

CHEMIOSMOSIS

Mechanism of photophosphorylation

The coupling reaction in which synthesis of ATP molecule takes during movement of H^+ across an H^+ gradient is called chemiosmosis. Peter Mitchell proposed chemiosmosis hypothesis in 1961. The mechanism for the ATP synthesis is chemiosmosis in cyclic and non- cyclic phosphorylation. It is a process that uses membranes during redox reaction for ATP production.

1. The membranes are impermeable to passive flow of protons.
2. The electron donors and acceptors are arranged in the membrane. They provide passage for the movement of protons.
3. The electron transport chain (ETC) pumps the protons (H^+) across the thylakoids. The movement of electron provides energy for the pumping of electron through the ETC. This energy is transferred into **potential energy**. The potential energy is stored in the form of **proton motive force**.
4. The hydrogen ions move down from the gradient through **ATP synthase complex**. The ATP synthase complexes are present within the thylakoid membranes. The ATP synthase enzyme uses the proton motive force for the synthesis of ATP.

DARK REACTION OR CALVIN – BENSON CYCLE OR C_3 CYCLE

The series of reactions in which carbon is fixed in the synthesis of sugar is called Calvin – Benson cycle. It takes place in the stroma of chloroplast.

Discovery of Calvin Benson cycle

Melvin Calvin, Benson and coworkers determined the detail of Calvin cycle. They used radioactive isotope of carbon (C^{14}) in CO_2. They performed experiments on unicellular algae Chlorella. They introduced the radioactive CO_2 to the algae. Photosynthesis took place. They used alcohol to stop the process of photosynthesis at different intervals. Then they removed various radioactive compounds and determined their chemical nature. They found following compounds:

1. After 1-2 seconds, radioactive C^{14} appeared in phosphoglyceric acid (PGA)
2. After 30 seconds, radioactive C^{14} was found in triose phosphate, fructose 1-6 phosphate and glucose phosphate.
3. After 30 mimutes, radioactive C^{14} appeared in six carbon sugars like glucoses, sucrose etc.
4. After 1 hour, C^{14} was found in some amino acids.

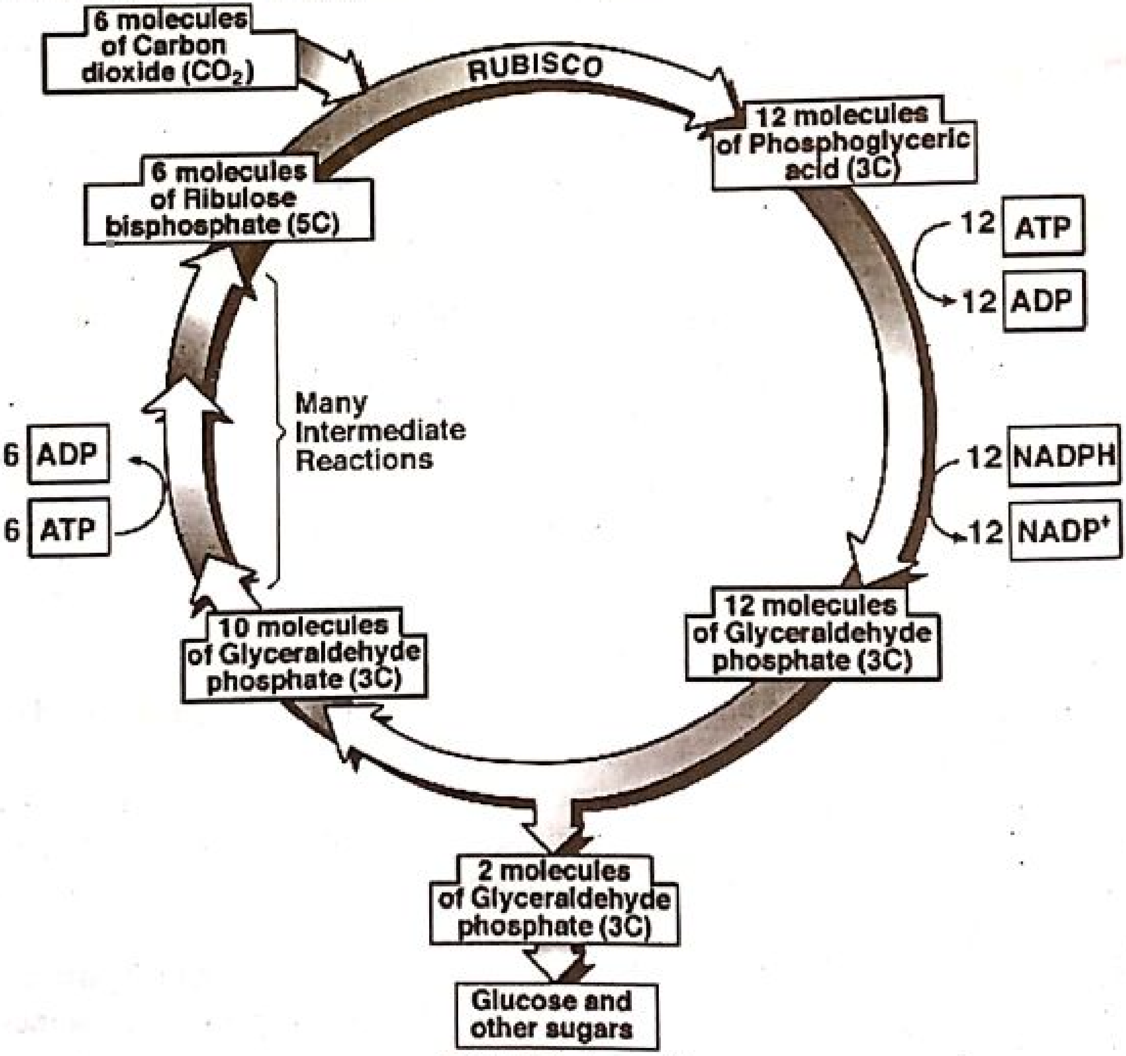

6 molecules of Carbon dioxide (CO_2)
RUBISCO
12 molecules of Phosphoglyceric acid (3C)
12 ATP
12 ADP
12 NADPH
12 NADP⁺
12 molecules of Glyceraldehyde phosphate (3C)
2 molecules of Glyceraldehyde phosphate (3C)
Glucose and other sugars
10 molecules of Glyceraldehyde phosphate (3C)
6 ADP
6 ATP
Many Intermediate Reactions
6 molecules of Ribulose bisphosphate (5C)

Fig: Calvin cycle

Mechanism of Calvin cycle

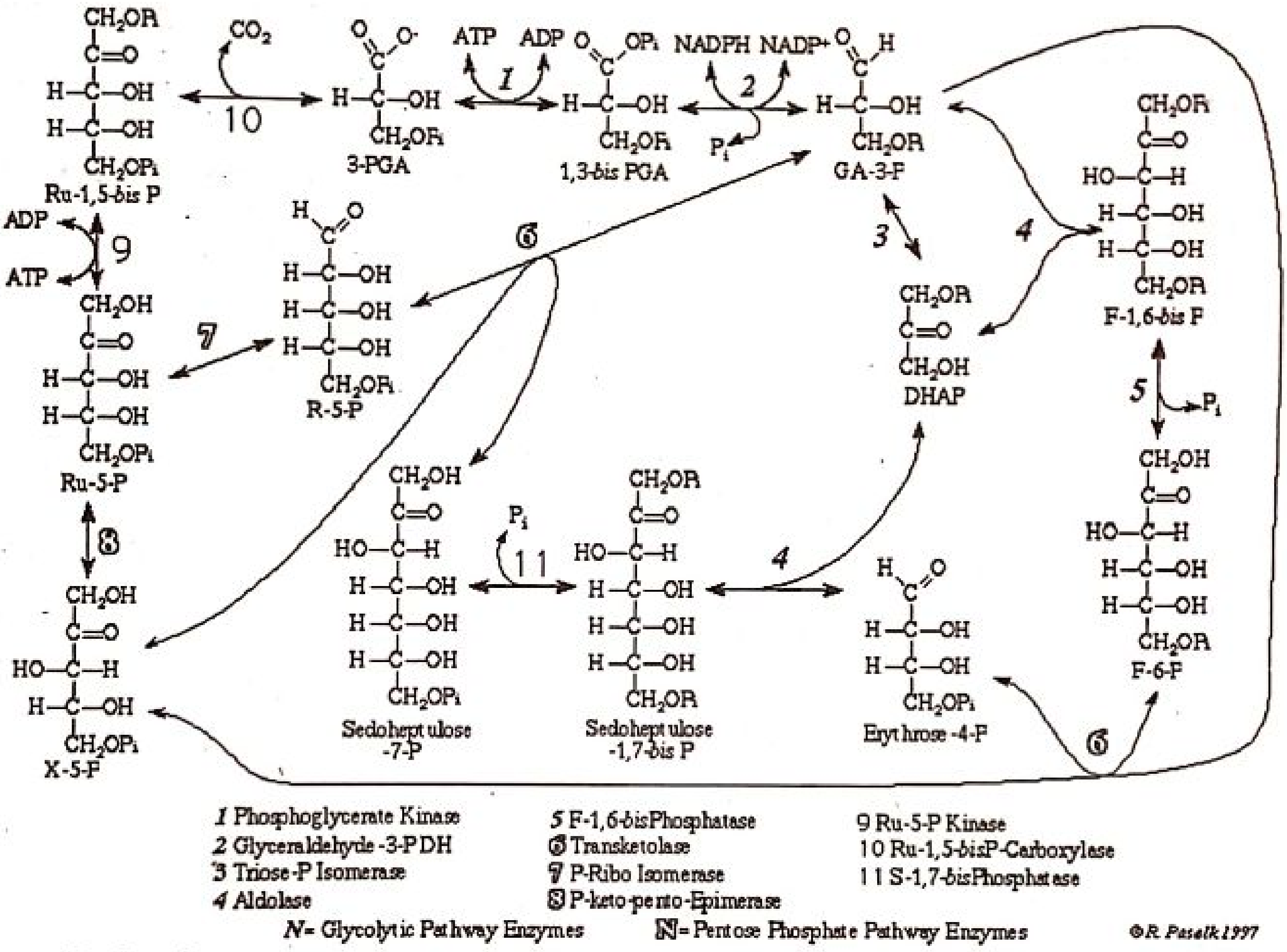
The Calvin cycle is composed of four steps.

1. Carbon fixation

Ribulose 1,5-bisphoshate (RuBP) is already present in the stroma of the chloroplast. CO_2 reacts with RuBP to form a six carbon compound. This six carbon compound is unstable.

It at once breaks into two molecules of 3-phosphoglycerate (PGA). The reaction is catalyzed by enzyme **Ribulose bisphosphate carboxylase.** This enzyme is commonly called **rubisco.**

Calvin Cycle (Dark Reactions of Photosynthesis)



2. Reduction

The ATP and $NADPH_2$ are used during this phase of reaction. The COOH group of 3-PGA is phosphorylated by ATP. It gives 1,3-bisphosphoglycerate. The 1,3-bisphosphoglycerate react with $NADPH_2$.It is reduced into 3-phosopglceraldehyle (PGAL). This reaction is controlled by enzyme **triose phosphate dehydrogenase**. This reaction can be written as:

$$PGA + ATP + NADPH_2 \longrightarrow PGAL + NADP + ADP + Pi$$

3. Regeneration of RuBP

RuBP is the starting point of CO_2. It must be regenerate for its reuse in the coming reaction. It is regenerated in following reactions.

(i) PGAL is converted into **dihydroxyacetone phosphate**.

(ii) Two molecules of dihydroxyacetone phosphate condense (aldol condensation) to give **fructose 1,6-bisphosphate**. It is hydrolyzed into **fructose 6-phosphate**.

(iii) Fructose 6-phosphate (6C) combines with a molecule of PGAL (3C). They combine to give two molecules of **erythrose 4 – phosphate (4C)** and **xylulose, 5-phosphate (5C).**

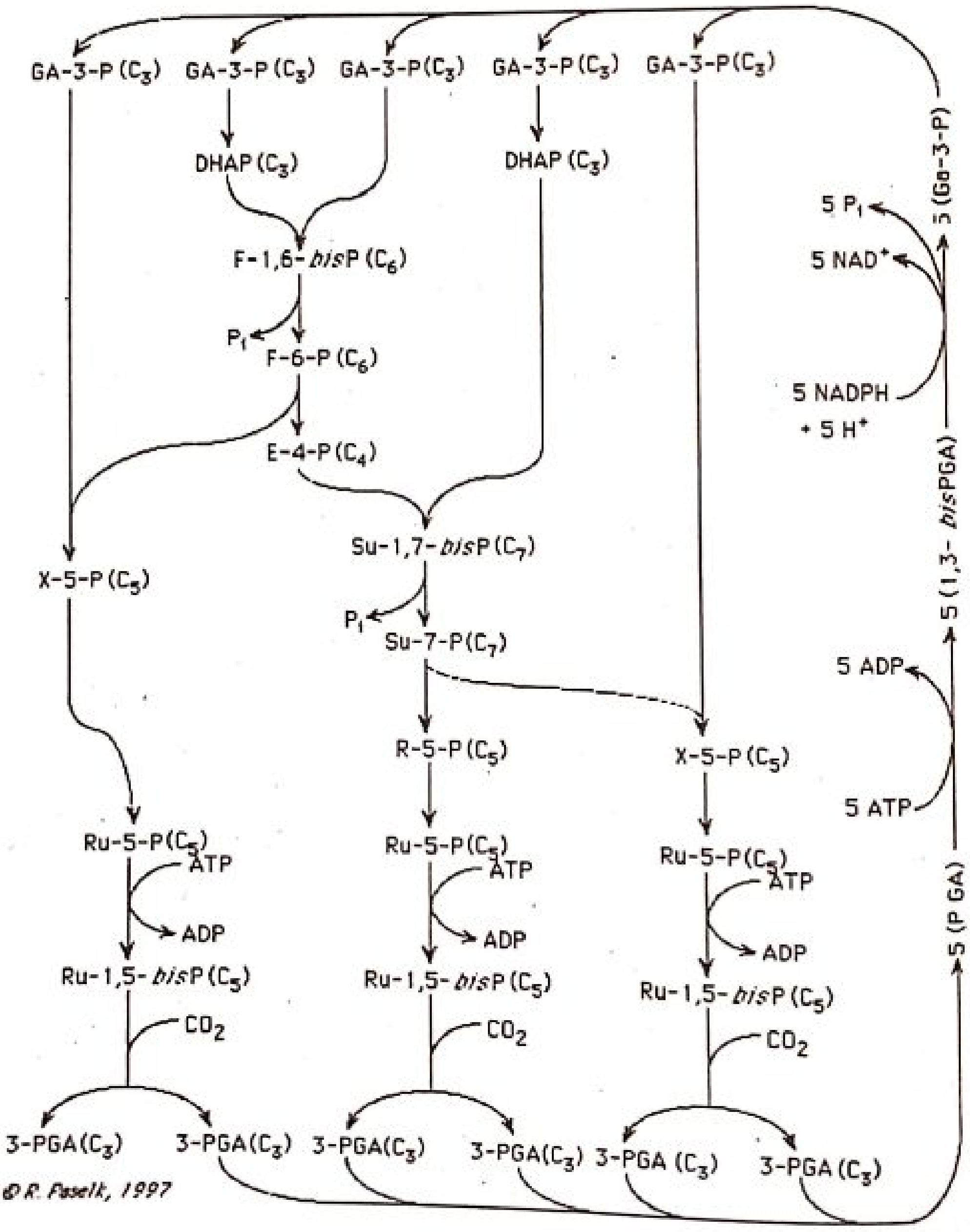
(iv) Erythrose 4 – phosphate (4C) combine with dihydroxyacetone phosphate (3C) to form **sedoheptulose 7- phosphate (7C).**

(v) Sedoheptulose 7- phosphate (7C) combine with PGAL (3C) to give two molecules of **xylulose 5-phosphate** (5C).

(vi) Two molecules of xylulose 5-phosphate arrange with each other to form two molecules of **Ribulose 5-phosphate.**

Ribulose 5-phosphate is phosphorylated by ATP. It gives **Ribulose-1,5-bisphospate (RuBP).**

Calvin Cycle Flow Diagram



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4. **Synthesis of final products**

Three molecules of CO_2 and three molecules of RuBP are used during Calvin cycle. It produces 6 molecules of PGAL. Only one molecules of PGAL come out of cycle. It is used for synthesizing glucose, starch etc. the remaining five molecules of PGAL are used in the regeneration of RuBP. PGAL of many cycles combine to form following compounds:

(i) **Carbohydrates:** Triose sugar combines to form glucose and fructose. Glucose and fructose combine to form sucrose. Many molecules of glucoses combine to form starch and cellulose.

(ii) **Lipids:** Some triose phosphates are converted into acetyl CoA. It is then converted into fatty acids.

(iii) **Proteins:** Some triose phosphate is converted into α-ketoglutrate in Krebs cycle. The α-ketoglutrate combines with ammonium ion to give different amino acids.

PHOTOSYNTHESIS IN C_4 PLANTS (Not included in syllabus)

The initial product of carbon dioxide fixation in some of the tropical and subtropical plants is **malic acid or malate**. Malate is 4-C compound. Therefore these plants are called C-4 plants. This cycle is also called **Hactch –Slack cycle**. C_4 cycle takes place in bundle sheath cells. These are the sheath of cells around the vascular bundles of the leaf. These cells contain a large number of chloroplasts. These chloroplasts contain enzyme PEP carboxylase. Rubisco is absent in them.

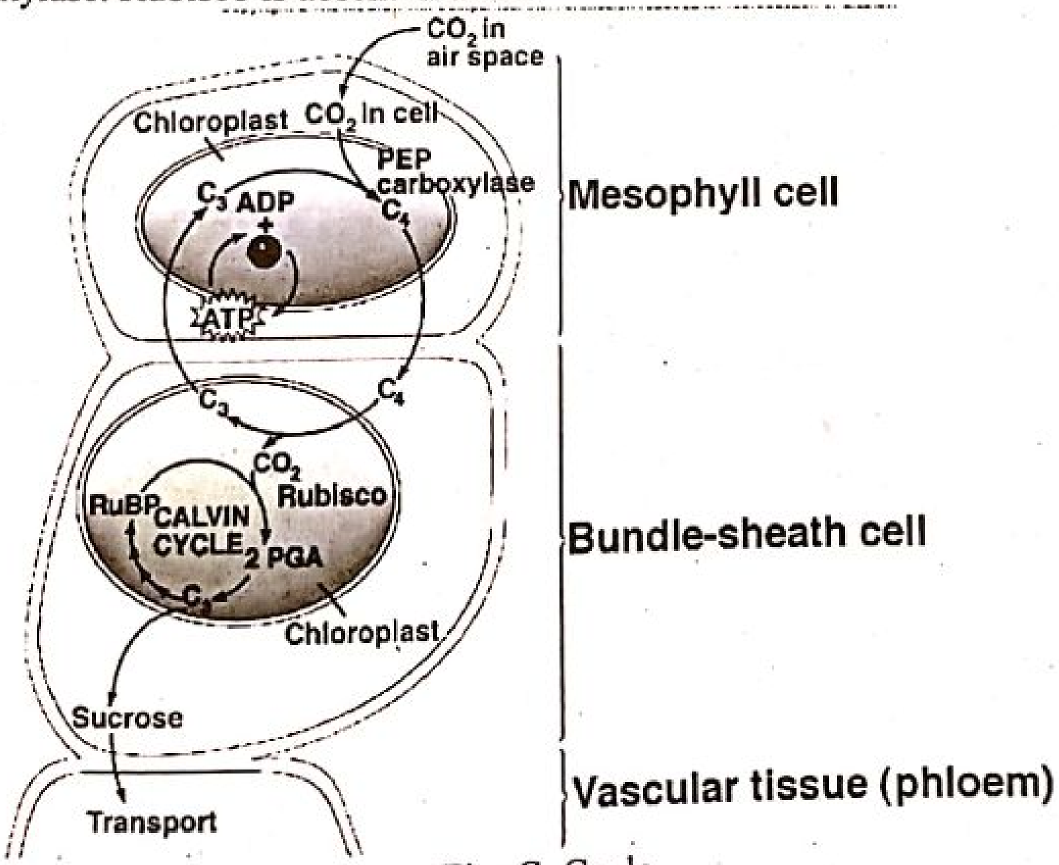


Fig: C_4 Cycle

Following reactions take place during C_4 cycle:

1. The CO_2 reacts with phosphoenol pyruvic acid (PEP) to form oxaloacetic acid. This

reaction takes place in the presence of the enzyme **phosphoenol pyruvate carboxylase (PEP carboxylase).**

2. The $NADPH_2$ reduce oxaloacetic acid into **malate** (malic acid). This reaction is catalyzed by malate dehydrogenase.
3. The malate is transported to the bundle-sheath cells. It releases CO_2 to from pyruvate (pyruvic acid). The CO_2 released is used in the Calvin cycle
4. Pyruvic acid reacts with ATP. It regenerates phosphoenol pyruvate (PEP). Thus it completes the cycle.

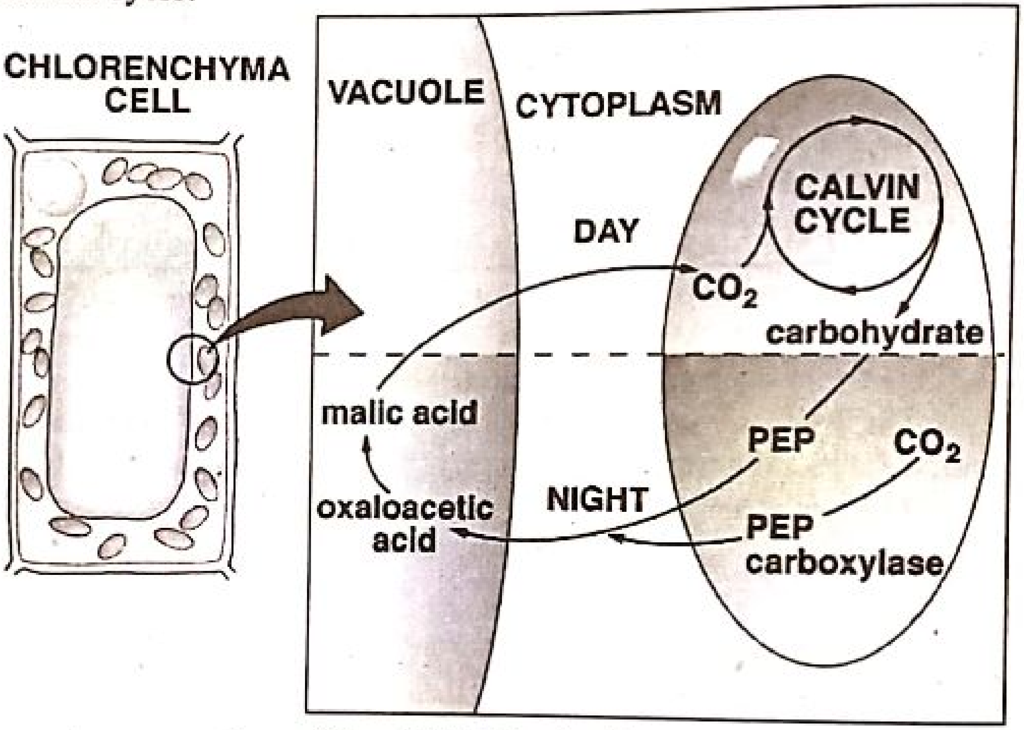


Fig: CAM Mechanism

CRASSULACEAN ACID METABOLISM (CAM)

(Not included in syllabus)

Crassulacean metabolism occurs in **succulents** plants. The CAM plants are without well developed palisade cells. They contain mostly spongy mesophyll. Bundle sheath cells are present. But they are similar to mesophyll cells. CAM plants from malic acid at night but it disappears during daylight. They use CAM mechanism to store CO_2 at night. Following reactions take place during CAM:

1. The stomata open at night. The CO_2 enters into the leaves. It combines with Phosophoenol pyruvate to form oxaloacetate. This reaction is catalyzed by the enzyme PEP carboxylase.
2. The $NADPH_2$ reduces the oxaloacetate to malate. This reaction is catalyzed by malate dehydrogenase. Most of the malate is stored in the vacuole during night time.
3. Stomata are closed at day time to prevent loss of water. Therefore, the entry of CO_2 is also stopped. The malic acid diffuses out of the vacuole into the cytoplasm. It is broken and it releases pyruvate and CO_2. Pyruvate reacts with ATP to regenerate

PEP.

The CO_2 enters into chloroplasts. It is fixed by Calvin cycle. Thus sugars and starch is synthesized.

THE CONCEPT OF LIMITING FACTORS

Sach developed three cardinal points for each factor affecting the photosynthesis. These cardinals have minimum, optimum and maximum values.

a) **Minimum:** It is the minimum value of a factor at which photosynthesis just starts. Photosynthesis does not occur below this point.

b) **Optimum:** It is the suitable value of a factor. Maximum photosynthesis occurs at this cardinal.

c) **Maximum:** It is the maximum value of a factor. Photosynthesis occurs at that point. But the amount of photosynthesis is much smaller. Photosynthesis stops above this point.

Plant physiologist determined minimum optimum and maximum values of different factor affecting the photosynthesis. Several factors operated simultaneously. They interact with one another. Therefore, different investigators obtained different values for these three cardinal points.

F.F. Blackman (1905) solved this problem. He gave the **"Principle of limiting factors". It is stated that when many factors affect on a process the rate of the process is limited by the pace of the slowest factor."** The factor that is lesser than required for the process is called the **slowest factor**. The principle operates when two or more factors act simultaneously.

Experiment of Blackman

1. **CO_2 as limiting factor:** He exposed a leaf to a light intensity. This light intensity is sufficient to utilize 5 mg of carbon dioxide per hour. If only I mg of the gas enters the leaf per hour, photosynthesis goes on at a certain rate. In this case the increase of intensity of light does not increase in the photosynthetic rate. The light is already present in excess. It is sufficient to utilize 1mg of carbon dioxide per hour. He increased the supply of carbon dioxide to 2 mg per hour. The rate of photosynthesis increased at the same light intensity. This shows that the carbon dioxide concentration determine the rate of photosynthesis. Thus carbon dioxide is the limiting factor.
2. **Light as limiting factor:** The rate of photosynthesis goes on increasing with an increase in the concentration of carbon dioxide. Finally, the supply of carbon dioxide reaches 5mg per hour. At this point the two factors have a maximum effect on photosynthesis. Now light intensity is just enough to utilize 5 mg. Further increase in the supply of carbon dioxide will have no effect on the rate of photosynthesis. Thus light has now become the limiting factor. Rate of photosynthesis can increase only if light intensity is increased.

FACTORS AFFECTING PHOTOSYNTHESIS

Many external and internal factors affect the rate of photosynthesis. The external or environmental factors are light intensity, carbon dioxide concentration and temperature. The internal factor influencing the photosynthesis is chlorophyll content of the leaves and protoplasmic factors.

1. Light

Light is essential for photosynthesis. Photosynthesis does not take place in dark. The sun is the main source of light energy. Both quality and intensity of light are important for photosynthesis.

(a) **Light Quality:** The light consists of rays of different wavelengths. Only red and blue light are effective for photosynthesis. Green light is reflected or transmitted. Therefore, it does not play role in photosynthesis. Light of wavelength longer than 700 run is not effective for photosynthesis for green plants. Experiments of **Engelmann** proved that maximum photosynthesis occurs in the red and blue part of the spectrum.

(b) **Light Intensity:** Photosynthesis begins at very low intensity. It becomes maximum at bright daylight. But it decreases in strong light. Different plants require different intensity of light. Most of light reaching green leaves is reflected or transmitted. Thus only a small part of light is absorbed. Thus only about 0.5 to 1.5% of light energy is in photosynthesis. Thus light is not a limiting factor at high intensity.

Light is a limiting factor at low intensity. Thus the rate of photosynthesis increases with an increase in light intensity. High light intensities affect the rate of photosynthesis. It increases the temperature of the leaves. Therefore, rate of transpiration increases. The stomata are closed. It stops the entry of CO_2. Thus photosynthesis is stopped. Light also cause photorespiration. Photorespiration reduces the yield.

2. Carbon dioxide

The atmosphere is the chief source of carbon dioxide. It contains only 0.03 % of the gas by volume. It is very small amount. Therefore, CO_2 remain a limiting factor. The increase in the amount of carbon dioxide increases the photosynthesis. This increase is more rapid up to I % of carbon dioxide concentration. But it slows down beyond this point. Higher concentrations have an inhibitory effect on photosynthesis. It is clear that increase in concentration of CO_2 increases the yield of plant

3. Temperature

A suitable temperature is necessary for photosynthesis. There are three cardinals of temperature for photosynthesis.

(a) **Minimum:** It is minimum temperature at which the photosynthesis starts. The plants of cold and temperate regions have lower values of these cardinals. But tropical plants have higher value of these cardinals. Minimum temperature for many lichens is -20°C. It is -35^0 C for some conifers. Photosynthesis hardly starts at about 5°C in tropical plants. Desert plants like cactus can carry on photosynthesis even at 55°C

(b) **Optimum:** Maximum photosynthesis occurs at that point. The optimum temperature also varies greatly. Photosynthesis increases with rise in temperature up to 25°C. This increase follows **Vant Hoff's law**. According to this law the rate of chemical reaction doubles for every rise of 10°C. This is true only if light or carbon dioxide is not the limiting factors.

(c) Maximum: It is the highest temperature at which photosynthesis can take place. There is an initial increase in the rate of photosynthesis at this temperature. But this is soon followed by a decline. Higher the temperature the more rapid is the decline. The decline may be due to one or more of the following causes:

- **(i)** Accumulation of the end products of photosynthesis.
- **(ii)** Inhibitory effect of high temperature on the activity of enzymes.
- **(iii)** Failure of carbon dioxide to diffuse rapidly.
- **(iv)** Increased consumption of the photosynthate in photorespiration
- **(v)** Destructive effect of high temperatures on chlorophyll.

4. Water

Water is one of the raw materials of photosynthesis. The amount of water actually used in photosynthesis is very small. Less than 1 percent water is absorbed by the plant. Therefore, it cannot be a limiting factor directly. But the water content of the leaf often acts as a limiting factor indirectly.

The limiting effect of water is indirect. It maintains the turgor of the assimilatory cells. The rate of photosynthesis decreases in the cells which have lost their turgor. The loss of turgor of guard cells closed the stomata. It reduces the rate of photosynthesis.

5. Oxygen

Photosynthesis does not take place in cells which lack oxygen. There are two reasons of this. First, the energy produced in oxygen respiration is necessary for photosynthesis. Second, oxygen is required for the production and maintenance of some substance. This substance is essential for photosynthesis. High concentrations of oxygen inhibit the rate of photosynthesis. It promotes photorespiration.

6. Leaf Anatomy

Many factors of leaf anatomy affect the rate of photosynthesis. These factors influences the diffusion of carbon dioxide thorough the stomata. They also effect on the amount of light reaching the chlorenchyma. These factors are:

- **(i)** Different leaves have different thickness of the cuticle and epidermis.
- **(ii)** They develop palisade. They have different sizes and distributions of the intercellular spaces.
- **(iii)** They have difference sizes, positions and distributions of the stomata.
- **(iv)** They develop different types of chlorenchyma and the vascular tissues.

7. Chlorophyll content

Chlorophyll is essential for photosynthesis. **Etiolated** plants and non-green tissues do not show photosynthesis. The green cells produce starch in variegated leaves. There are two views about the affect of chlorophyll on photosynthesis:

(i) Willstatter and Stoll: They believe that the rate of photosynthesis is not proportional to the amount of chlorophyll content. The rate of photosynthesis depends on the concentration of enzymes and chlorophyll.

(ii) Emerson (1927): He found a direct relationship between the amount of food formed and the chlorophyll content.

8. Protoplasmic factor

Photosynthesis does not start immediately after the appearance of chlorophyll in very young leaves. It starts after some time. Same thing happens when plants are transferred from dark to light. Thus some internal factor is present in the protoplasm of the cells. This is called **"the unknown factor" or the "protoplasmic factor"** It is enzymatic in nature. **Arnon** (1954) has demonstrated that cell free chloroplasts are capable of carrying out photosynthesis. This indicates that protoplasm is not necessary for photosynthesis. Thus the chloroplasts are the complete photosynthetic units. They contain all the necessary enzymes.

PRODUCTS OF PHOTOSYNTHESIS

The products of photosynthesis are the carbohydrates and oxygen. Four carbohydrates, D-glucose, D-fructose, sucrose and starch are commonly are formed in the green cells during photosynthesis. Plant physiologists and biochemists have tried to find the first product of this process. But still it is not clear which the first product of photosynthesis. There are following products of photosynthesis:

1. **Hexoses:** According Weevers the first carbohydrates were the hexoses. After that sucrose and later starch appeared. Thus the carbohydrates appeared in the order of their complexity. The sucrose and starch are formed from hexoses by following equation.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O$$

$$(C_6H_{12}O_6)_n + H_2O \longrightarrow \underset{\text{Starch}}{(C_6H_{12}O_6)_n}$$

2. **Sugar phosphate:** Calvin used carbon dioxide containing radioactive carbon (C^{14}). He found that the first carbohydrate produced in photosynthesis was sugar phosphate. The first free sugar was sucrose. Glucose and fructose appeared later on. Thus it is not essential for free hexoses to accumulate before sucrose and starch are formed. Thus the phosphorylated sugars are the precursors of these substances.
3. **Amino acids:** The products other than carbohydrates like amino acids and related compounds may be formed as result of photosynthesis.
4. **Starch:** Starch is accumulated in the chloroplasts of most species after photosynthesis. Starch is not the first product of photosynthesis. It is the product of a secondary reaction called **starch synthesis**. It is formed by the condensation of sugar. The rate of starch synthesis depends upon on the rate of photosynthesis. Starch synthesis is an entirely independent process from photosynthesis. It starts after the process of photosynthesis. It can proceed only when sugar is present in the cells. Leaves of many species do not form starch. Yet photosynthesis takes place in them. Starch synthesis also takes place in the non-green cells of the stem.

5. **Oxygen:** It is a by-product of photosynthesis. It has great significance in nature. It is the most important means of returning oxygen to the atmosphere. The ratio of the volume of oxygen evolved to the volume of carbon dioxide taken in photosynthesis is called the photosynthetic ratio or **photosynthetic quotient**. Willstatter and Stoll found that the value of this ratio is unity.

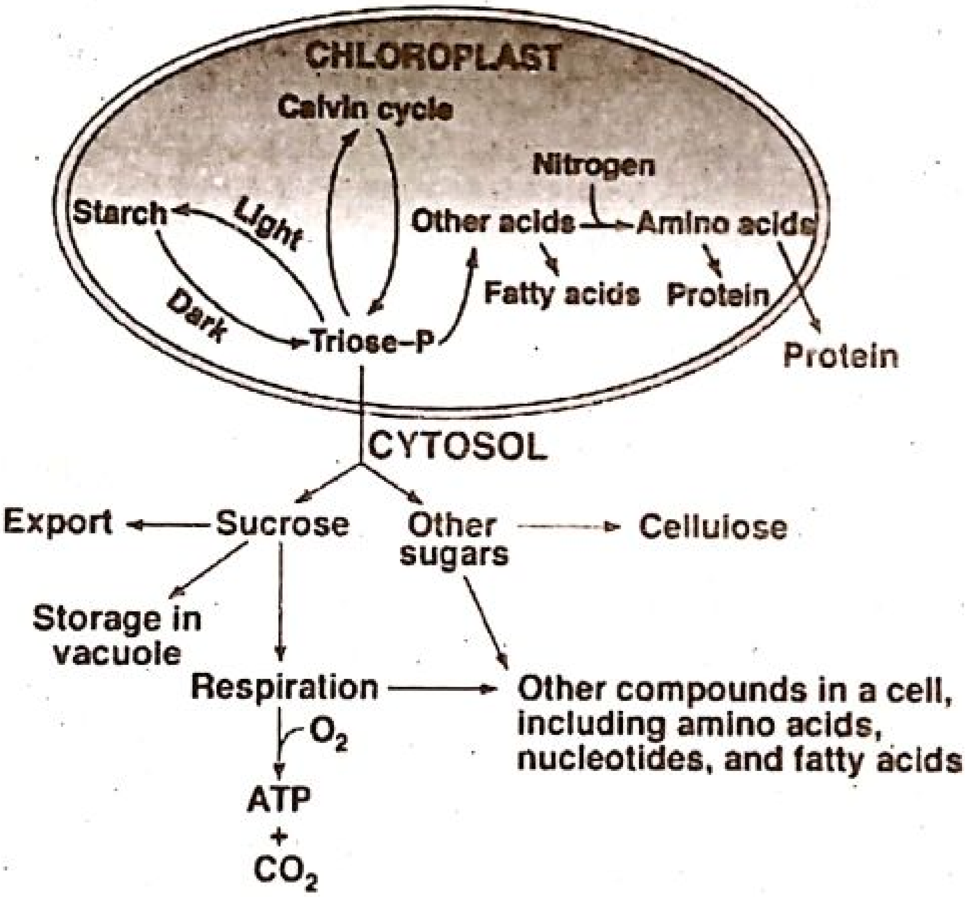


Fig: Photosynthetic products

(Not included in syllabus)

MEASUREMENT OF PHOTOSYNTHESIS

The rate of photosynthesis is measured by one of the following methods: By measuring (1) the volume of CO_2 consumed (2) volume of oxygen liberated (3) amount of carbohydrate accumulated.

1. OXYGEN EVOLVED

It is the simplest method. It this case, number of bubbles of oxygen are counted given out in unit time by green aquatic plants like Hydrilla. But there is objection on this method.

a) The gas evolved is not pure oxygen. It also contains some carbon dioxide and nitrogen.

b) Another objection is that bubbles are not always of uniform size. Wilmott passes the bubbles through the nozzle of a tube immersed in distilled water. Now the bubbles escape from the nozzle is of uniform size.

In another method the evolved oxygen is combined catalytically with hydrogen to form water in the presence of palladium. It can give exact amount of oxygen evolved during photosynthesis.

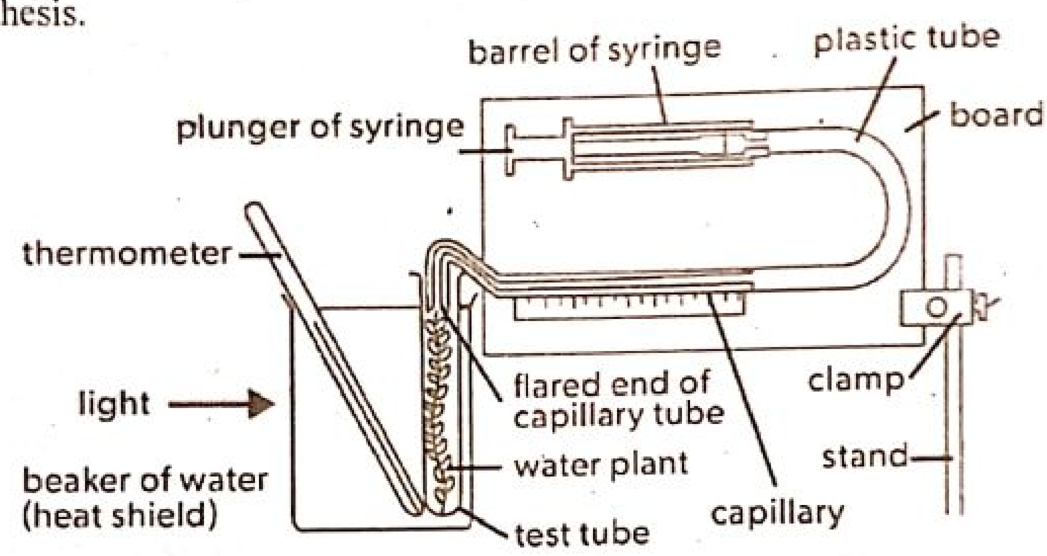


Fig: Photosynthometer

(b) CARBON DIOXIDE ABSORBED

Air of known carbon dioxide content is passed through a chamber. This chamber contains photosynthetic material. Some of the carbon dioxide is used up in the process. The unused carbon dioxide is passed through a vessels containing soda lime. It gives the percentage of unused CO_2. This amount is deducted from the total CO_2 supplied. It gives the total amount of CO_2 used during photosynthesis. Following methods are used to estimate the exact amount of CO_2 and O_2 released.

1. **Eudiometer Method:** It gives the amount of carbon dioxide absorbed and oxygen evolved simultaneously. A leaf is placed in an eudiometer tube. This tube contains air of known carbon dioxide content. The tube is sealed off by inverting its open end over mercury. It is placed in light. Then air inside the eudiometer is analyzed for its carbon dioxide and oxygen content.
2. **Photosynthometer:** It was developed by Ganong. It is a convenient laboratory method of analyzing the gas contents. The photosynthometer consists of three parts: (a) a glass bulb A, (b) a graduated tube C, and (c) a connecting link.

(c) INCREASE IN THE DRY WEIGHT

Dry weight method was adapted by **Sachs**. Photosynthesis increases the dry weight of plant. It can be measured in the form of dry weight. This method has following steps:

1. A plant is placed in darkness. Cuttings from its leaves are taken. They are cut into discs of uniform sizes. These discs are then heated in oven. Their dry weight is estimated.
2. Another plant is illuminated in light. Its leaves are taken. These leaves are divided into discs. Their dry weight is determined.
3. Dry weight of both the leaves is estimated.

Some of the products of photosynthesis are used during photosynthesis. So it is not an accurate method.

IMPORTANT DIFFERENCES

Absorption and Action spectrum

Absorption spectrum	Action spectrum
1. The Plot showing absorption of light of different wave lengths by a compound is called absorption spectrum.	1. The plot showing relative effectiveness of different wavelengths of light in photosynthesis is called action spectrum.
2. It is measured by spectrophotometer.	2. It is measured by simple method. The plant is illuminated with light of different wavelengths. The relative amount of CO_2 consumed or oxygen released during photosynthesis for each wave length is estimated.
3. Absorption spectrum indicates that the absorption is maximum in the blue and red part of the spectrum.	3. Action spectrum shows that the chlorophyll is the photosynthetic pigment.
4. The peaks of absorption spectrum of chlorophylls are not broader	4. The peaks of the action spectrum of photosynthesis are comparatively broader.
5. The valleys of action spectrum are deep.	5. The valleys of the action spectrum are narrow and not deep.

Non-cyclic and cyclic electron flow

Non-cyclic electron flow	Cyclic electron flow
1. In non-cyclic electron flow, electron does not return back to same excited chlorophyll.	1. In cyclic electron flow, there is returning back of the same excited electrons to the excited chlorophyll by producing a molecule of ATP.
2. Both photosystems II and I are involved in it.	2. Only photosystem II is involved in it.
3. End productive of non-cyclic electron flow is ATP and NADPH.	3. Only molecule of ATP is produced during non-cyclic electron flow.
4. It is most common electron flow. It regularly, supply ATP and NADPH for photosynthesis.	4. It is less common electron flow. It is a short circuit to supply ATP.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Photosynthesis	Photosynthesis (photo-light, synthesis-putting together) may be defined as the process in which the green plants synthesize carbohydrates from carbon dioxide and water, using the energy of sunlight.
Absorption spectrum	A plot (graph) showing absorption of light of different wavelength by a pigment is called absorption spectrum.
Photolysis	The splitting of water and release of oxygen during

	photosynthesis is called photolysis.
Cyclic phosphorylation	The returning back of the same excited electrons to the excited chlorophyll by producing a molecule of ATP it is called cyclic phosphorylation.
Chemiosmosis	The coupling reaction in which synthesis of ATP molecule takes during movement of H^+ across an H^+ gradient is called chemiosmosis.
Calvin cycle	The series of reactions in which carbon is fixed in the synthesis of sugar is called Calvin – Benson cycle.
Principle of limiting factors	It is stated that when many factors affect on a process the rate of the process is limited by the pace of the slowest factor.
Vant Hoff's law	According to this law the rate of chemical reaction doubles for every rise of 10°C.

MODEL SUBJECTIVE QUESTIONS

1. **Describe process of photosynthesis.**
2. **Write note on action and absorption spectrum.**
3. **Describe non-cyclic phosphorylation.**
4. **Describe cyclic phosphorylation.**
5. **Describe Kelvin cycle.**
6. **Give factors affecting the rate of photosynthesis.**
7. **What is the concept of limiting factor?**

SHORT QUESTIONS

1. Define photosynthesis.

Ans: Photosynthesis (photo-light, synthesis-putting together) may be defined as the process in which the green plants synthesize carbohydrates from carbon dioxide and water, using the energy of sunlight.

2. What are raw materials for photosynthesis?

Ans: The raw materials in this process are water and carbon dioxide. Water is absorbed by the roots from the soil in the vascular plants. It is transported up to the photosynthetic organs through the xylem. The carbon dioxide is absorbed by the aerial parts of the plants from the atmosphere.

3. Differentiate between action and absorption spectrum.

Ans: A plot (graph) showing absorption of light of different wavelength by a pigment is called absorption spectrum. The plot showing relative effectiveness of different wavelengths of light in photosynthesis is called action spectrum.

4. What are photosystems?

Ans: **Photosynthetic pigments are organized into clusters called photosystems.** These photosystems absorb and utilize the solar energy efficiently in the thylakoid membranes.

5. What is Hill's reaction?

Ans: The process in which $NADPH_2$ and ATP are formed in the presences of light is called light reaction or photochemical phase of photosynthesis. It was studied by Robert Hill. So it is also called **Hill's reaction.**

6. Define Principle of limiting factors.

Ans: It is stated that when many factors affect on a process the rate of the process is limited by the pace of the slowest factor.

7. What are the carbohydrates products of photosynthesis?

Ans: According Weevers the first carbohydrates were the hexoses. After that sucrose and later starch appeared. Thus the carbohydrates appeared in the order of their complexity.

8. What is Vant Hoff's law?

Ans: According to this law the rate of chemical reaction doubles for every rise of 10°C.

9. Name the electron carrier involved in non-cyclic phosphorylation.

Ans: Plastocynin, Cytochrome C and plastoquine.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. Number of CO_2 moleucles used during photosynthesis.
(a) 2 (b) 5 (c) 6 (d) 1

2 The free energy change during photosynthesis is:
(a) 680Kcal (b) 560 (c) 686 (d) 654

3. The concept of limiting factor was given by:
(a) Sayer (b) Dixon (c) Blackman (d) None

4. According to Vant Hoff's law the rate of chemical reaction doubles for every rise of
(a) 10°C (b) 20°C (c) 30°C (d) 40°C

5. This light energy is used to synthesize NADPH and:
(a) Glucose (b) ATP (c) Rubisco (d) starch

6. The visible spectrum is:
(a) 280 to 750nm (b) 380 to 650nm (c) 380 to 750nm (d) 300 to 700nm

7. The series of reactions in which carbon is fixed in the synthesis of sugar is called:
(a) light reaction (b) C4 reaction (c) Calvin – Benson cycle (d) none

8. The first carbohydrate product of photosynthesis is:
(a) 2 carbon (c) 3 carbon (d) 4 carbon (d) 6 carbon

9. The atmosphere contains only ________0.03 % of the CO_2 by volume.
(a) 0.03 (b) 0.05 (c) 0.07 (d) 0.09

Answers: 1. (c) 2. (c) 3. (c) 4. (a) 5. (b) 6. (c) 7. (c) 8. (c) 9. (a)

Fill in blanks

1. A plot (graph) showing absorption of light of different wavelength by a pigment is called ___________ spectrum.
2. The plot showing relative effectiveness of different wavelengths of light in photosynthesis is called _________ spectrum.
3. Principle of limiting factors is stated that when many factors affect on a process the rate of the process is limited by the pace of the _________ factor.
4. The visible spectrum is of wavelength from ________to 750nm.
5. The plot showing relative effectiveness of different wavelengths of light in photosynthesis is called _________spectrum.
6. ________spectrum is given by all the pigments.

7. Photosynthetic pigments are organized into clusters called ________.
8. Light reaction is also called ________'s reaction.
9. The formation of ATP during non-cyclic flow is called ________ phosphorylation.
10. The splitting of water and release of oxygen during photosynthesis is called ________.
11. The synthesis of ________ due to light energy is called photophosphorylation.
12. ATP is synthesized during ________.
13. Two molecules of xylulose 5-phosphate arrange with each other to form two molecules of ________ 5-phosphate.
14. The initial product of carbon dioxide fixation in some of the tropical and subtropical plants is ________.
15. ________ developed three cardinal points for each factor affecting the photosynthesis.
16. Etiolated ________ plants and non-green tissues do not show photosynthesis.
17. Arnon ______ has demonstrated that cell free chloroplasts are capable of carrying out photosynthesis.
18. Only red and ______ light are effective for photosynthesis.
19. ________ proposed chemiosmosis hypothesis in 1961.
20. An enzyme NADP ________ transfers the electrons from Fd to NADP.

Ans 1. Absorption 2. Action 3. Slowest 4. 380 5. action 6. Absorption 7. Photosystems 8. Hill 9. non-cyclic 10. Photolysis 11. ATP 12. Chemiosmosis 13. Ribulose 14. Malate 15. Sach 16. Etiolated 17. Arnon 18. Blue 19. Mitchell 20. reductase

True/False

1. The raw materials in this process are water and carbon dioxide.
2. Products of photosynthesis in green plants are a simple proteins like sugar and oxygen.
3. The light energy is used to synthesize NADPH and ATP
4. The entire range of radiations is known as visible spectrum.
5. Photosynthetic pigments are organized into clusters called photosystems.
6. Dark reaction is also called Hill's reaction.
7. The formation of ATP during non-cyclic flow is called non-cyclic phosphorylation.
8. The splitting of water and release of oxygen during photosynthesis is called photolysis.
9. The synthesis of ATP due to light energy is called photophosphorylation.
10. ATP is synthesized during dark reaction.
11. An enzyme NADP reductase transfers the electrons from Fd to NADP.
12. John proposed chemiosmosis hypothesis in 1961.
13. The reactions in which carbon is fixed in synthesis of sugar is called Calvin – Benson cycle.
14. Sach developed three cardinal points for each factor affecting the photosynthesis.
15. Only green and blue light are effective for photosynthesis.
16. The atmosphere contains only 0.03 % of the CO_2 by volume.
17. Photosynthesis hardly starts at about 5°C in tropical plants.
18. Etiolated plants and green tissues do not show photosynthesis.
19. Arnon has demonstrated that cell free chloroplasts are capable of carrying out photosynthesis.
20. Starch is not the first product of photosynthesis.

Answers: **1. T, 2. F.** Carbohydrate, 3. T, 4. F. Electromagnetic 5. T, 6. F. Light 7. T, 8. T, 9. T. 10. F. chemiosmosis 11. T, 12. F Mitchell, 13. T, 14. T, 15. F. red, 16. T, 17. T, 18. F. non-green 19. T, 20. T

Chapter 6

RESPIRATION

Syllabus

1. Definition and mechanism
2. Glycolysis
3. Krebs cycle
4. Electron transport chain
5. Oxidative phosphorylation
6. Anaerobic respiration
7. Respiratory substrates and respiratory quotients

RESPIRATION

The series of oxidation reduction reactions in which substances (glucose) are oxidized to carbon dioxide and oxygen and energy is released is called respiration. Plants require a constant supply of energy. This energy performs biological work. The ATP provides this energy. All animals can generate ATP by breaking down organic nutrients. These nutrients are carbohydrates, fats, and proteins. The energy is released. This energy is used to join ADP and phosphate (Pi) to form ATP.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 36ATP$$

The first step of respiration is glycolysis. The breakdown of organic nutrients begins in a step by step series of chemical reactions called glycolysis. The end product of glycolysis is pyruvate. The pyruvate is then further broken down. This breakdown occurs in two processes:

a) **Aerobic respiration:** It takes place in the presence of free oxygen. It includes Krebs cycle and electron transport chain.

b) **Anaerobic respiration:** It takes place in the absence of free oxygen. This process is called fermentation.

Glycolysis and fermentation (anaerobic processes) take place in the cytoplasm of a cell. But aerobic respiration takes place in the mitochondrion.

It is believed that evolution of glycolysis and fermentation occurred in earliest organism. Two factors support this view:

1. The enzymes remained dissolved in the cytoplasm during eukaryotic cell evolution. These enzymes were not enclosed in membranous organelles. Therefore, glycolysis and fermentation occur in the cytoplasm. Thus the origin of glycolysis and

fermentation took place before to the evolution of complex organelles.

2. Similarly these reactions occur in the earliest primitive environment of earth. This atmosphere did not contain free oxygen. So these reactions are also older than aerobic respiration.

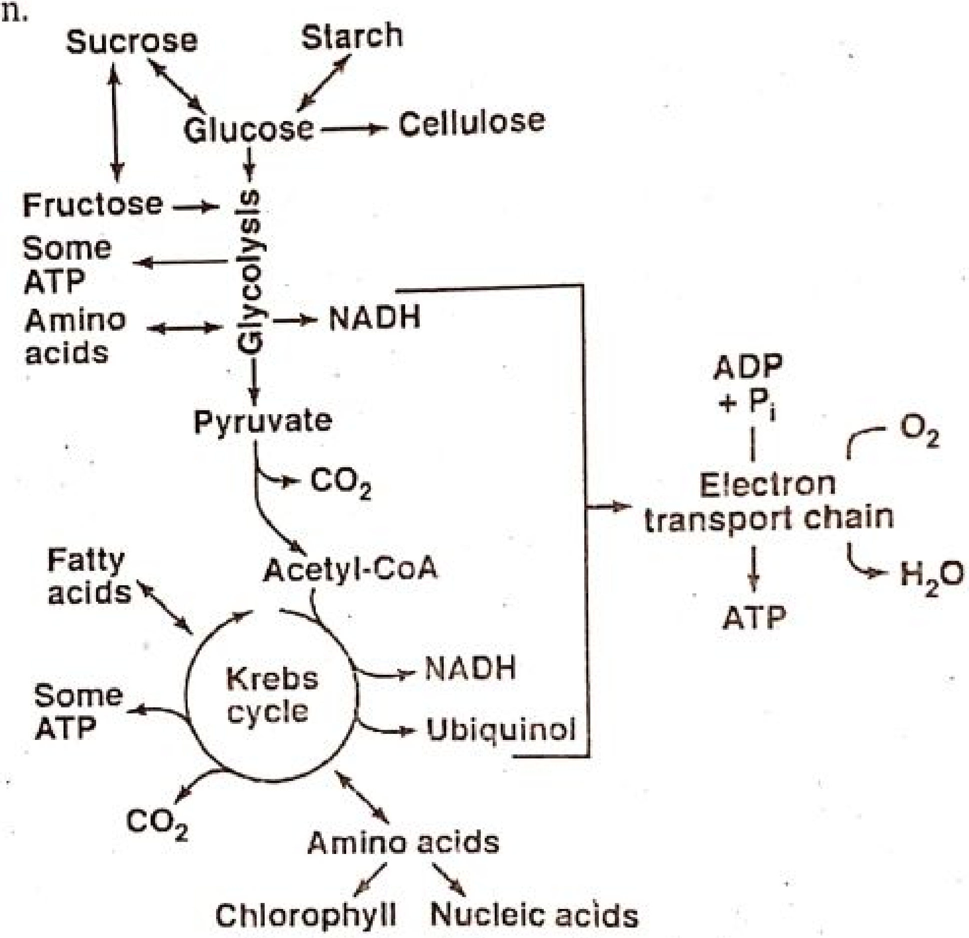


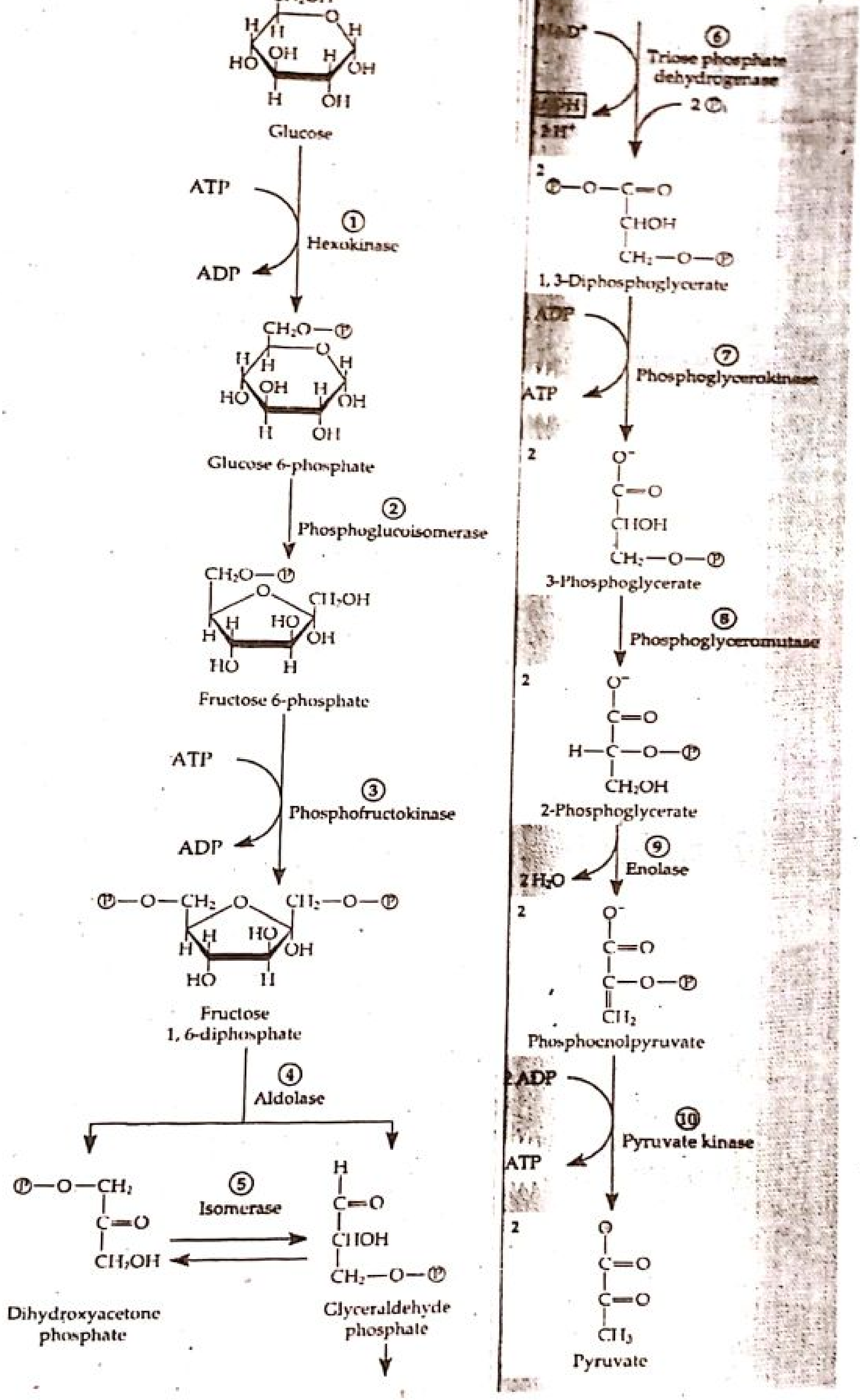
Fig: Different steps of respiration

GLYCOLYSIS

Glycolysis is the initial step of catabolic chemical reactions. It occurs almost in all the cells. Six-carbon glucose molecule is broken down into two molecules **pyruvate** during glycolysis. Pyruvate is a three carbon compound. There is net production of two molecules of ATP during glycolysis. Each molecule of glucose produces four molecules of ATP during glycolysis. But two ATP molecules are used to rearrange the glucose molecule. They form new six-carbon compounds. Therefore, the net energy yield from glycolysis is only two ATP molecules. Glycolysis does not efficiently harvest energy from glucose. But it was the only to generate ATP molecules for millions of years during the anaerobic stages of early life on earth. Following reactions take place during glycolysis:

(a) Energy Investment Phase

1. **Step 1:** Glucose enters the cell. It is phosphorylated by the enzyme **hexokinase**. This enzyme transfers a phosphate group from ATP to the sugar. The plasma membrane is impermeable to ions. So the electrical charge of the phosphate group traps the sugar


Glucose
ATP
①
Hexokinase
ADP
Glucose 6-phosphate
②
Phosphoglucoisomerase
Fructose 6-phosphate
ATP
③
Phosphofructokinase
ADP
Fructose 1, 6-diphosphate
④
Aldolase
⑤
Isomerase
Dihydroxyacetone phosphate
Glyceraldehyde phosphate
NAD⁺
⑥
Triose phosphate dehydrogenase
NADH
2H⁺
2 Ⓟi
2
1, 3-Diphosphoglycerate
ADP
⑦
Phosphoglycerokinase
ATP
2
3-Phosphoglycerate
⑧
Phosphoglyceromutase
2
2-Phosphoglycerate
⑨
Enolase
2 H₂O
2
Phosphoenolpyruvate
2 ADP
⑩
Pyruvate kinase
ATP
2
Pyruvate

in the cell. Phosphorylation of glucose makes the molecule more chemically reactive.

2. **Step 2:** Glucose 6-phosphate is rearranged by enzyme isomerase. It is converted it to its isomer, fructose 6-phosphate
3. **Step 3:** In this step, another molecule of ATP is used in glycolysis. An enzyme **phosphofructokinase** transfers a phosphate group from ATP to the sugar.
4. **Step 4:** This is reaction from which glycolysis gets its name. An enzyme **aldolase** breaks the sugar molecule into two different three- carbon sugars: glyceraldehydes phosphate and dihydroxyacetone phosphate. These two sugars are isomers of each other.
5. **Step 5:** Another enzyme catalyzes the reversible conversion between the two three—carbon sugars. The reaction reaches equilibrium in test tube. The next enzyme in glycolysis uses only glyceraldehyde phosphate as its substrate.

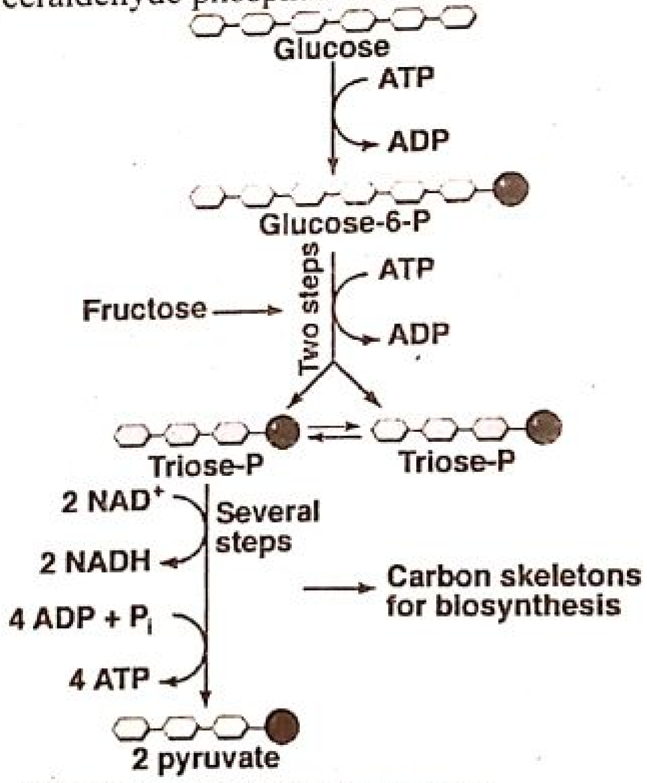


Fig: Glycolysis (an overview)

(b) Energy-Yielding Phase

6. **Step 6:** An enzyme now catalyzes two reactions. First, glyceraldehyde phosphate is oxidized by the transfer of electrons and H^+ to NAD. It forms $NADH^+$. This reaction is very exergonic (—10.3 kcal/mol). The enzyme uses this energy to attach a phosphate group to the oxidized substrate. It forms 1,3 bisphosphoglyceric acid The source of the phosphate is inorganic phosphate. It is always present in the cytosol.
7. **Step 7:** Finally, glycolysis produces some ATP. The phosphate group added in the previous step is transferred to ADP. It break 1,3 bisphosphoglyceric acid to form 3-phosphoglycerate. This compound is not a sugar. The carbonyl group that characterizes a sugar has been oxidized to a carboxyl group. It is an organic acid.

8. **Step 8:** An enzyme **mutase** relocates the remaining phosphate group. It forms 2-phosphoglycerate. It prepares the substrate for the next reaction.
9. **Step 9:** An enzyme **enolase** removes a water molecule and form a double bond in the substrate. It forms **phosphoenol pyruvate**, or PEP. This makes the substrate very unstable.

Step 10: An enzyme **pyruvate kinase** transfers the phosphate group from PEP to ADP. So it produces more ATP. Since this step occurs twice for each glucose molecule, so there is a net gain of two ATP molecules. Thus glucose has been broken down and oxidized to two molecules of pyruvate. It is the end-product of the glycolytic pathway.

KREBS CYCLE (Tricarboxylic Acid Cycle)

Krebs cycle is a series of reactions in which the pyruvate from glycolysis is oxidized to CO_2. The Krebs cycle was discovered by Hans Krebs in the 1930s. Two electron carriers act as hydrogen acceptors. These are:

a) **Nicotinamide adenine dinucleotide (NAD)**
b) **Flavin adenine dinucleotide (FAD)**

These are reduced to NADH and $FADH_2$. Three molecules of CO_2 are generated from each pyruvate molecule during this phase of the cycle. Some energy is also produced in the form of ATP. Most of the remaining energy is in the form of NADH and $FADH_2$. These two molecules are transferred into the electron transport chain. The pyruvate is first changed in **Acetyl CoA**. The Acetyl CoA then enters into the Krebs cycle. Following reactions occur during Krebs cycle:

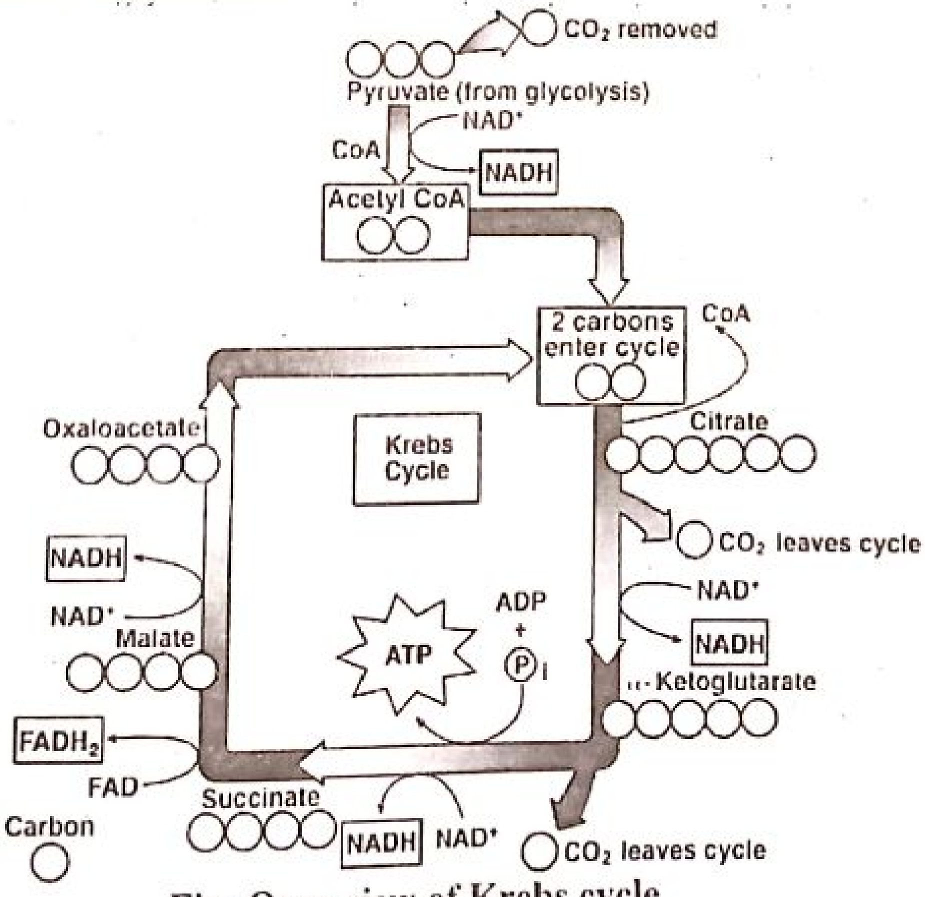


Fig: Over view of Krebs cycle

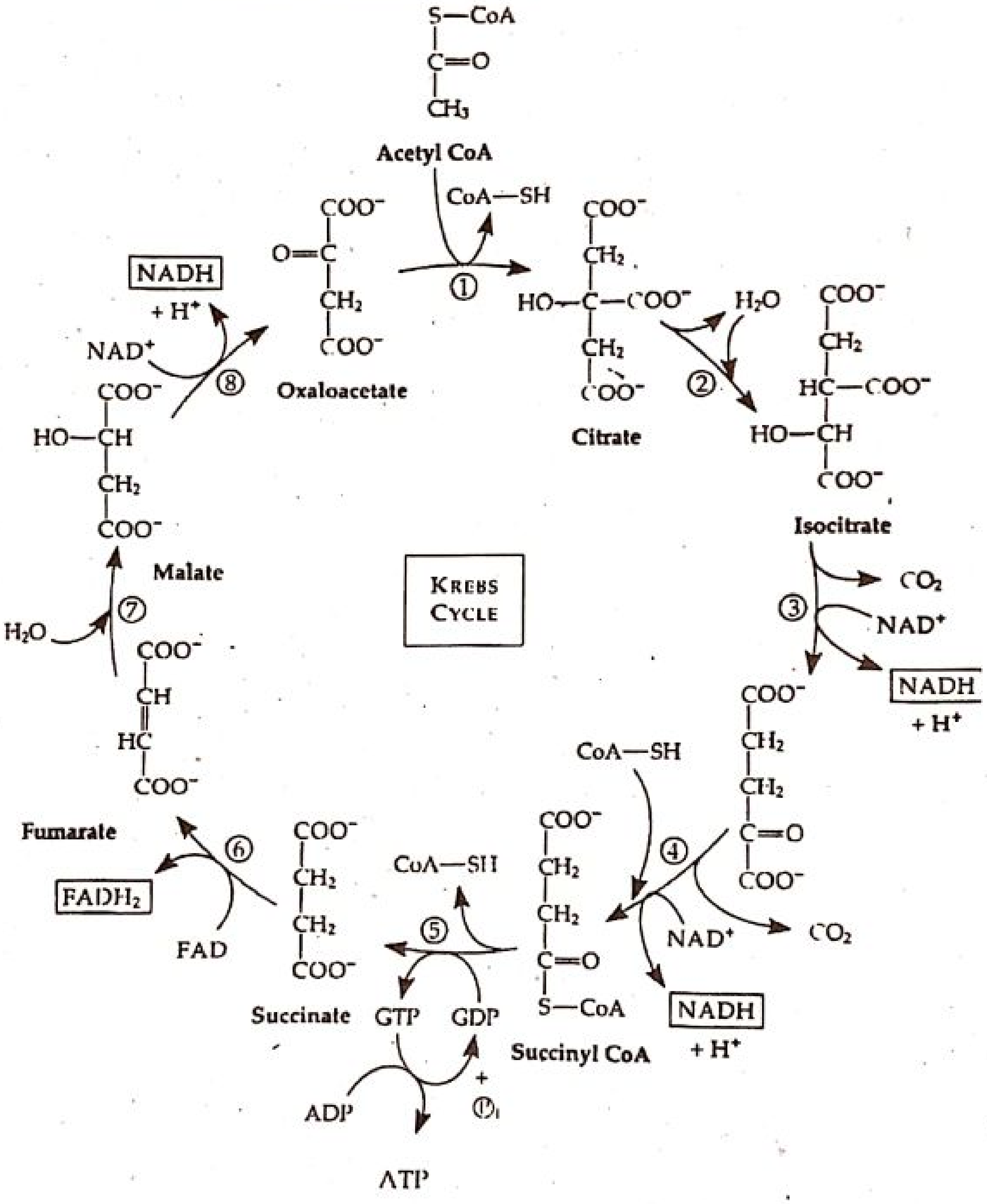


Fig: Different reactions of Krebs cycle

1. **Step 1:** Acetyl CoA adds its two-carbon fragment to **oxaloacetate**. Oxaloacetae is a four-carbon compound. The unstable bond of acetyl CoA is broken attaches to the acetyl group. The product is the six-carbon citrate. This reaction is controlled by enzyme **citrate synthase**.
2. **Step 2:** A molecule of water is removed and another is added back. The net result is the conversion of citrate to its isomer **isocitrate**. It is controlled by enzyme **aconitase**.
3. **Step 3:** The substrate loses a CO_2 molecule in the presence of enzyme

dehydrogenase. Thus the remaining five carbon compound is oxidized. It reduces NAD to NADH and **α-ketoglutrate** is formed.

4. **Step 4:** This step is catalyzed by a multienzyme complex. CO_2 is lost. The remaining four-carbon compound is oxidized and electrons are transferred to NAD to form NADH. The compound is then attached to coenzyme. Thus **Succinyl CoA** is formed.
5. **Step 5:** Substrate level phosphorylation occurs in this step. CoA is replaced by a phosphate group and **succinate** is formed. The phosphate group is then transferred to GDP. It forms guanosine triphosphate (GTP). GTP is similar to ATP.
6. **Step 6:** Two hydrogens from succinate are transferred to form $FADH_2$. It produces **Fumarate.**
7. **Step 7:** Bonds in the substrate are rearranged by the addition of a water molecule and **malate** is formed.
8. **Steps 8:** In this step another molecule of NADH is produced. It regenerates oxaloacetate. The **oxaloacetate** is ready to enter into another reaction.

Products of Krebs cycle

Krebs cycle gives following products from the oxidation one molecule of acetyl CoA:

1. Three molecules of CO_2
2. Three molecules of $NADH_2$
3. One molecules of $FADH_2$
4. One molecule of ATP

ELECTRON TRANSPORT CHAIN

The collection of electron carrier molecules embedded in the inner membrane of the mitochondrion is called electron transport chain. The folding of the inner membrane forms cristae. These cristae contains electron carrier in the form of prosthetic groups. Prosthetic groups are tightly bound to molecules of proteins. The prosthetic groups are non protein components. These prosthetic groups alternate between reduced and oxidized states during electron transport chain. They accept and donate electrons. There are following steps of electron transport chain:

1. **NADH to FMN:** Electrons are removed from food during glycolysis and the Krebs cycle. These electrons form $NADH_2$. $NADH_2$ transfers the electrons to flavoprotein. Flavoprotein is the first molecule of electron transport chain. The flavoprotein has a prosthetic group called mononucleotide (FMN).
2. **FMN to Fe.S:** The FMN passes electrons to an iron-sulfur protein (Fe-S). It is one of a family of proteins in which both iron and sulfur tightly bound. It is a redox reaction. The FMN returns to its oxidized form.
3. **Fe.S to Ubiquinone (Q):** The iron protein then passes the electrons to a compound ubiquinone. This electron carrier is the only member of the electron transport chain that is not a protein. A molecule of ATP is synthesized during this transfer.
4. **Ubiquinone to Cytochromes:** Most of the remaining electron carriers between Q and oxygen are proteins called **cytochromes.** Their prosthetic group is called haem group. Haem group is an organic ring. It is surrounded by a single iron atom. The electron

chain has several types of cytochromes. Each group has a different protein with a haem group. These are:

a) Cytochrome b
b) Cytochrome c_1
c) Cytochrome c
d) Cytochrome a
e) Cytochrome a_3

The last Cytochrome passes its electrons to oxygen. It also picks up a pair of hydrogen ions from aqueous medium to form water. Two molecules of ATP are produced during this transfer of electron through the cytochromes.

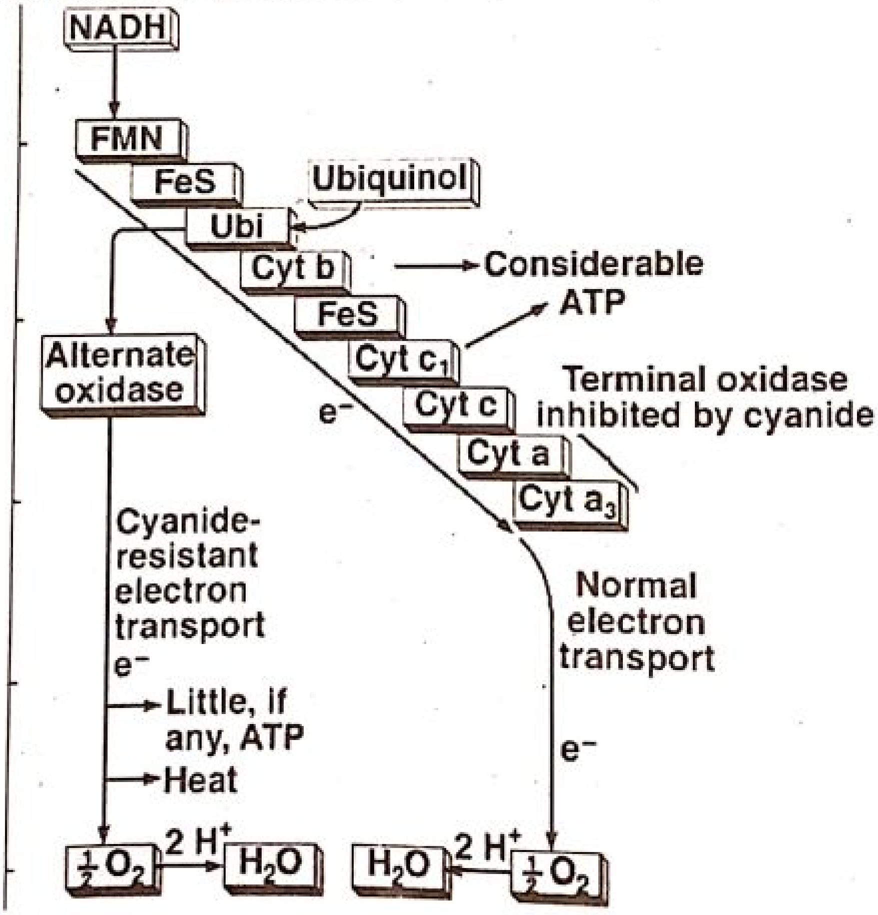


Fig: Electron transport chain

$FADH_2$ an alternate source of electron

Another source of electrons for the transport chain is $FADH_2$. It is produced during Krebs cycle. $FADH_2$ adds its electrons to transport chain at a lower energy level than that of NADH. Therefore, the electron transport chain provides about one third less energy than $FADH_2$.

The electron transport chain makes no ATP directly. Its function is to pass electrons from food to oxygen. It breaks a large free energy drop into a series of smaller steps that release energy in manageable amounts. Mitochondria synthesize ATP during a mechanism called chemiosmosis.

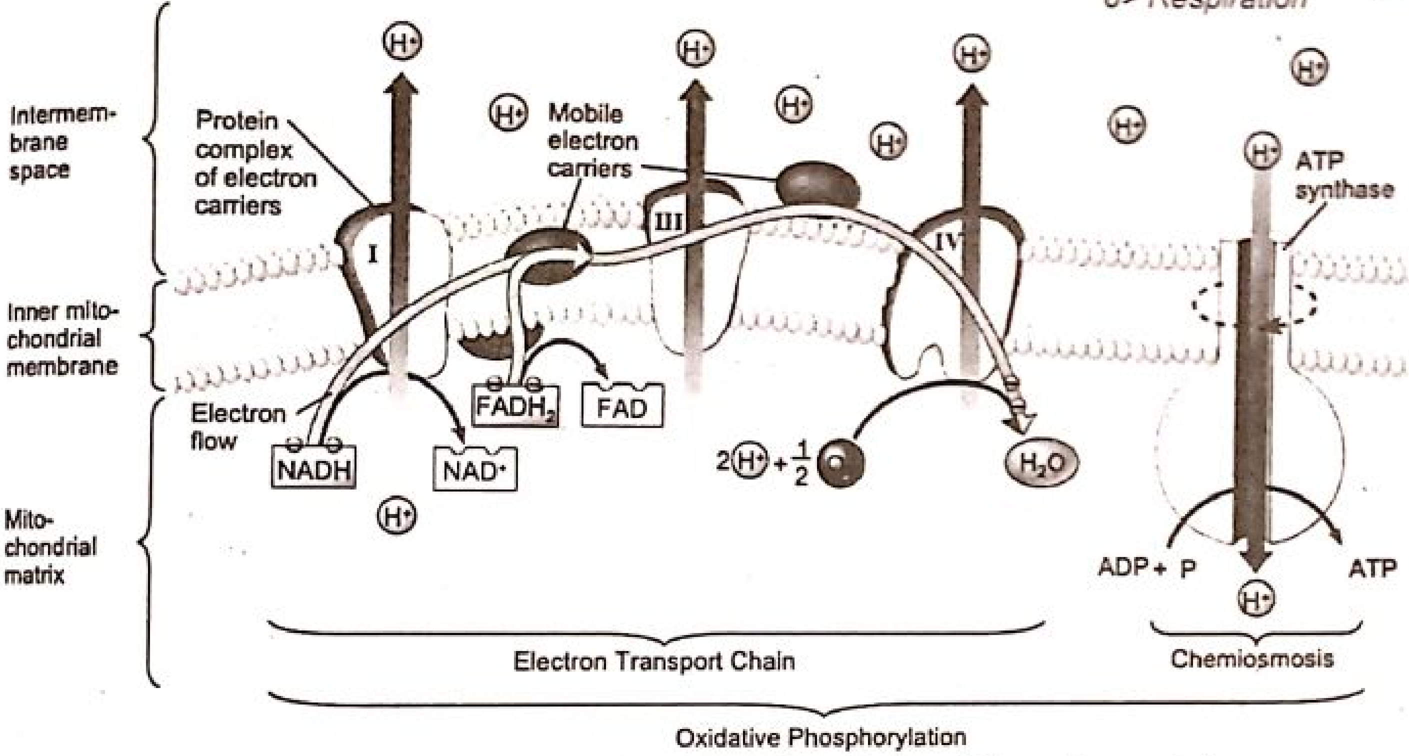


Fig: Mechanism of Oxidative phosphorylation (Chemiosmosis)

OXIDATIVE PHOSPHORYLATION

The synthesis of ATP molecule in the presence of oxygen is called oxidative phosphorylation. Oxidative phosphorylation takes place during respiratory chain. Three ATP molecules are formed during three steps of the respiratory chain. This process can be expressed by following equation:

$$\mathbf{NADH + H^+ + 3ADP + 3Pi + 1/2O_2 \longrightarrow NAD^+ + 4H_2O + 3ATP}$$

The Pi is an inorganic phosphate. The molecular mechanism of the oxidative phosphorylation is associated with the respiratory chain. These respiratory chains are present in the **inner membrane of mitochondria**. The mechanism of oxidative phosphorylation is chemiosmosis.

The coupling reaction in which synthesis of ATP molecule takes during movement of H^+ across an H^+ gradient is called chemiosmosis. It is a process that uses membranes during redox reaction for ATP production.

1. The electron transport chain (ETC) pumps the protons (H^+) across the inner membrane of mitochondria. The movement of electron provides energy for the pumping of electron through the ETC. This energy is transferred into **potential energy**. The potential energy is stored in the form of H^+ gradient across the membrane. It is called **electro motive forces.**
2. The inner membrane of the mitochondria is folded into **cristae.** These cristae have F_1 particles. The protons (H^+) are pumped from matrix into intermembrane space through this inner membrane. They come back from the intermembrane space into matrix and pass through the F_1 particles.
3. The F_1 particles contain an **ATP synthase enzyme**. So it uses the energy of proton to

synthesize the molecules of ATP.

Difference between Photophosphorylation and Oxidative phosphorylation

Photophosphorylation	Oxidative phosphorylation
1. **The synthesis of ATP due to light energy is called photophosphorylation.**	1. **The synthesis of ATP molecule in the presence of oxygen is called oxidative phosphorylation.**
2. As the electrons move down the chain, their energy goes on decreasing. This energy is used by the thylakoid membranes of chloroplast to synthesize ATP.	2. Normally, oxidative phosphorylation takes place during respiratory chain. Three ATP molecules are formed during three steps of the respiratory chain.
3. It occur during transfer of electron through Electron transport chain of photosystem II of chloroplast.	3. It takes place during transport of electrons through ETC present in the inner membrane of mitochondria.

ENERGY BALANCE OF RESPIRATION

The eukaryotic cell obtains a net gain of 36 ATP molecules from the breakdown of each glucose molecule.

1. **Glycolysis:** Glycolysis produces four ATP molecules. But two are used in the glycolytic reactions. The two molecules of NADH formed during glycolysis produce six ATP molecules. But two are used in the reactions that transport the NADH electrons across the inner mitochondrial membrane into the matrix.
2. **Formation of acetyl COA:** One molecule of NADH is produced for each pyruvate converted into acetyl-coenzyme A. One molecule of CO_2 is released as acetyl coenzyme A enters into the Krebs cycle.
3. **Krebs cycle:** Two more ATP molecules are produced in the Krebs cycle. Similarly, six NADH and two $FADH_2$ molecules are produced during Krebs cycle.
4. **Electron Transport Chain:** The six NADH from the Krebs cycle and two NADH from the entry of acetyl-coenzyme A into the electron transport chain. They yield 24 ATP molecules. The oxidation of the two molecules of $FADH_2$ produced four more molecules of ATP. The net gain from all of these reactions is 36 molecules of ATP.

Reaction	**No. of $NADH_2$ or $FADH_2$ formed**	**No. of ATPs released**
Glycolysis	2	2
Formation of Acetyl CoA	2	
Kerbs cycle	$6NADH_2 +$ $2FADH_2$	2
Electron Transport chain	Total $NADH_2 = 10$ (each $NADH_2$ molecule give three ATPs) Total $FADH_2 = 2$ (each $FADH_2$ gives two ATP)	$10 \times 3 = 30$ $2 \times 2 = 4$
Total ATPs		**$38 - 2 = 36$**

ANAEROBIC RESPIRATION: FERMENTATION

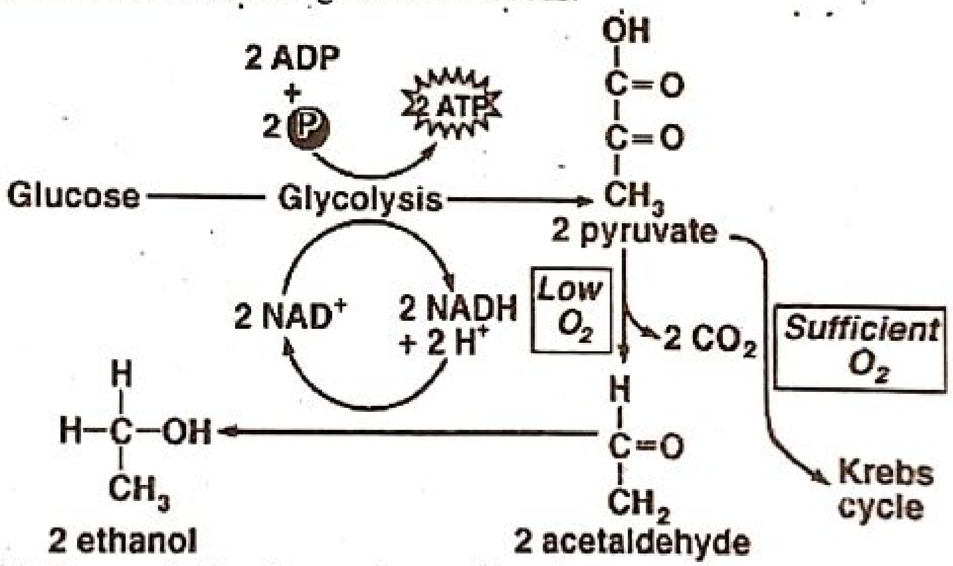
The respiration which takes place in absence of oxygen is called anaerobic respiration. There are two views about the origin of fermentation:

(a) It is an evolutionary bypass. Some organisms use to keep glycolysis functioning under anaerobic conditions.

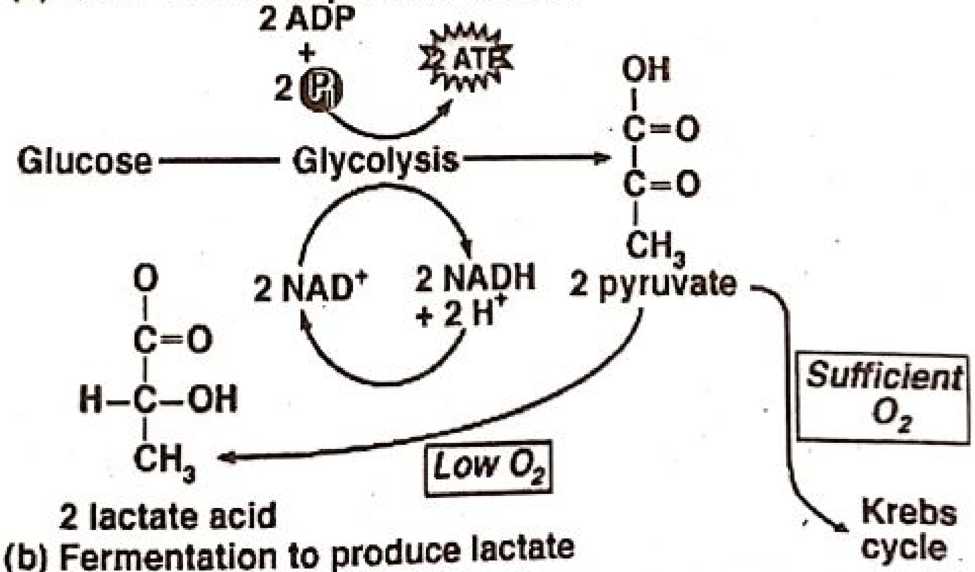
(b) It is a biochemical remnant. It has evolved very early in the history of life. At that time the earth's atmosphere contained no oxygen.

Strong evidences are present. These evidence shows that the common descent of organisms from primitive cells. In these cells glycolysis and fermentation first appeared. It still persists.

The glycolysis generates the hydrogen atoms. These atoms are donated to organic molecules in fermentation. Following reactions occur:



(a) Fermentation to produce ethanol



(b) Fermentation to produce lactate

Fig: Fermentation (a) Alcoholic fermentation (b) Lactate fermentation

1. Lactic acid fermentation

The NADH reduces the Pyruvate to form lactic acid. This reaction occurs in the mammalian muscles and certain fungi. The animal used $NADH_2$ to reduce the pyruvate. This reaction is controlled by an enzyme **lactate dehydrogenase.**

2. Alcoholic fermentation

The $NADH_2$ reduces the pyruvate into alcohol. It takes place in some fungi (yeast) and bacteria. The glucose is not completely degraded during fermentation. Therefore, a large amount of unusable energy still remains in the products. Only two molecules of ATP are formed during glycolysis and no more ATP is produced. Fermentation is used only to regenerate NAD. It produces ethanol as by product. This reaction is controlled by enzyme pyruvate decarboxylase and alcohol dehydrogenase.

Two types of organisms can carry out fermentation:

a) **Obligative anaerobic:** Obligative anaerobic organisms include certain types of bacteria. These organisms survive only in the complete absence of molecular oxygen. Its example is **clostridium** sp.

b) **Facultative anaerobic:** Facultative anaerobic organisms and tissues include certain bacteria, yeasts, and cells. These organisms can ferment nutrients in absence of oxygen. It also generates some ATP. It also provides NAD for glycolysis. Facultative anaerobic organisms and tissues carry out more efficient energy harvesting in the presence of oxygen.

Difference between Anaerobic and Aerobic Respirations

Anaerobic respiration	Aerobic respiration
1. The respiration take place in the absence of oxygen is called anaerobic reparation.	1. The respiration take place in the presence of oxygen is called anaerobic reparation.
2. In this case, incomplete breakdown of glucose take place.	2. In this case, complete breakdown of glucose take place.
3. The end product of anaerobic respiration is lactic acid and alcohol.	3. There is complete breakdown of glucose. So there is no end product.
4. It produce only two molecules of ATP from one molecule of glucose.	4. It produces 36 molecules of ATP from one molecule of glucose.

Difference between Alcoholic and Lactic acid fermentation

Alcoholic fermentation	Lactic acid fermentation
1. The pyruvic acid is broken down into alcohol and CO_2 by alcoholic fermentation.	1. In this case, each pyruvic acid molecule is converted into lactic acid $C_3H_6O_3$.
2. Alcoholic fermentation takes place in some primitive cells and some eukaryotic cells like yeasts.	2. It occurs in muscle cells of human and in other animals.
3. It takes in special types of anaerobic bacteria and yeast.	3. It takes place during extreme physical activities like sprinting. The oxygen cannot be transported to the cells during such extreme activities. Therefore, pyruvic acid is changed into **lactic acid.**

RESPIRATORY SUBSTRATE

The organic substances of the cells used up in the respiratory process are called

respiratory substrate. There are following respiratory substances.

1. **Carbohydrates:** Simple carbohydrates are the chief respiratory material. Starch and sucrose are the most important respiratory substrate. The reserve carbohydrates like starch are first transformed into the simple carbohydrates. Then they are consumed in respiration.
2. **Fats:** Fats are respiratory substrate in oily seeds. Fats are first converted into sugars. Then they are used in respiratory process. For example, castor oil seed are rich in fats reserve. These fats are converted into sucrose during germination of seed. Fats are broken into fatty acts. These fatty acids are then changed into acetyl CoA. So they enter into the Krebs cycle.
3. **Proteins:** Sometimes, carbohydrates or fats are not available. Then proteins are utilized. Some seed are protein rich like bean. In such seeds, proteins acts respiratory substrate. Proteins are broken into amino acids. Different amino acids enter into different reactions of Krebs cycle.

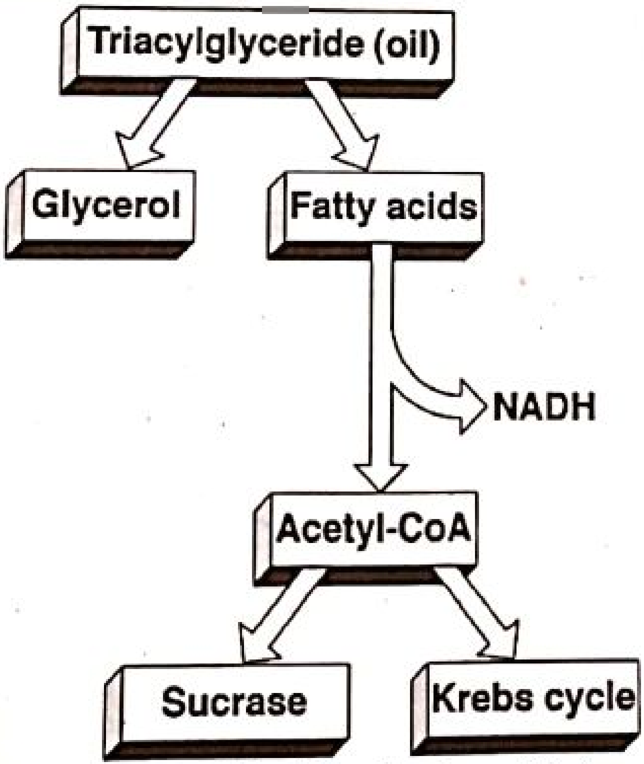


Fig: Respiration of fats

RESPIRATORY QUOTIENT (R.Q)

The ratio of the volume of carbon dioxide give out to the volume of oxygen absorbed (CO_2/O_2) is called the respiratory quotient. There are different values of RQ for different compounds and processes.

1. Respiratory quotient of carbohydrates

The value of RQ is 1 for hexose sugars.

$$\underset{}{C_6H_{12}O_6} + \underset{6}{6O_2} \longrightarrow \underset{6}{6CO_2} + 6H_2O$$

As the ratio is 6/6 = 1. But deviations may occur from this value.

2. **Respiratory quotient of fats:** Fats are poorer in oxygen than carbohydrates. So their value of respiratory quotient is less than one. The value of respiratory quotient for fats is 0.7. Such respiration takes place during the germination of fatty seeds. Thus,

$$\mathbf{2C_{51}H_{98}O_6 + 145O_2 \longrightarrow 102CO_2 + 98H_2O}$$

Tripalmitin

$R.Q = CO_2/O_2 = 102/145 = 0.7$. It is less than one.

3. **Respiratory quotient of protein:** The value of respiratory quotient for proteins is about 0.5.
4. **Respiratory quotient of organic acids:** The organic acids are rich in oxygen. Their value of respiratory quotient is greater than one. For example, the value of respiratory quotient is 4 for oxalic acid. It is 1.6 for tartaric acid and 1.3 for malic acid.

$$\mathbf{2(COOH)_2 + O_2 \longrightarrow 42CO_2 + 2H_2O}$$

$R.Q = CO_2/O_2 = 4/1 = 4$

5. **Respiratory quotient in succulent plants:** Incomplete oxidation of carbohydrates occurs in succulent plants like Opuntia. Oxygen absorbed does not oxidize the carbohydrates completely. In such plants the respiration of carbohydrates takes place at night. They produce organic acids. Their respiratory quotient is less than 1 or zero.

$$\mathbf{2C_6H_{12}O_6 + 3O_2 \longrightarrow 3C_4H_6O_5 + 3H_2O}$$

Malic acid

$R.Q = CO_2/O_2 = 0/3 = 0$

6. **Respiratory quotient in anaerobic respiration:** Oxygen is not used in the anaerobic respiration. Therefore, the vale of respiratory quotient for anaerobic respiration is more than 1.

Determination of respiratory quotient

Respiratory quotient is determined by **Ganong's respirometer**. It is composed of manometer. The manometer is filled with mercury.

1. **Carbohydrates:** The volume of carbon dioxide released is equal to the volume of oxygen absorbed for the oxidation of carbohydrates. Therefore, the level of the liquid will remain constant. Now caustic potash is added to the apparatus. It absorbs carbon dioxide. The amount of CO_2 is measured. The amount of oxygen is equal to amount of CO_2.
2. **Fats:** Less CO_2 is produced by fats than oxygen. So level of liquid in the graduated limb rises. The amount of CO_2 is determined by adding caustic potash.

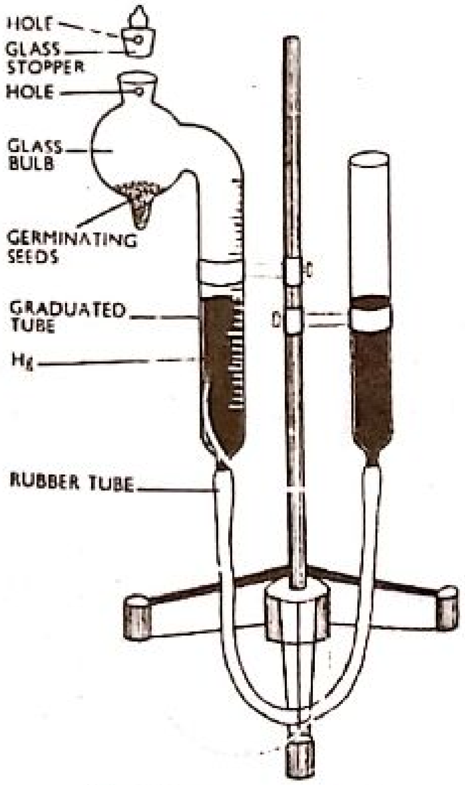


Fig. 16.20 Ganong's Respirometer

Difference between Respiration and Photosynthesis

Respiration	Photosynthesis
1. Oxygen is absorbed and CO_2 is released during respiration.	1. CO_2 is absorbed and oxygen is released.
2. Respiration is catabolic or destructive process. In this case, glucose molecule is broken and energy is released.	2. Photosynthesis is an anabolic or constructive process.
3. It takes place in all living cell.	3. It takes place in cell with chlorophyll.
4. It takes place day and night, irrespective of the light.	4. It takes place only in the presence of light at day time.
5. A plant losses its weight due to respiration.	5. A plant gain weight due to photosynthesis.
6. The volume of carbon dioxide released and oxygen released may or may not be equal.	6. The volume of CO_2 absorbed and oxygen released are always equal.
7. It may take place even in the absence of oxygen.	7. It cannot take place in the absence of carbon dioxide.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Respiration	The series of oxidation reduction reactions in which substances (glucose) are oxidized to carbon dioxide and oxygen and energy is released is called respiration.
Aerobic respiration	Aerobic respiration takes place in the presence of free oxygen. It includes Krebs cycle and electron transport chain.
Anaerobic respiration	Anaerobic respiration takes place in the absence of free oxygen. This process is called fermentation.
Krebs cycle	Krebs cycle is a series of reactions in which the pyruvate from glycolysis is oxidized to CO_2.
Electron transport chain	The collection of electron carrier molecules embedded in the inner membrane of the mitochondrion is called electron transport chain.
oxidative phosphorylation	The synthesis of ATP molecule in the presence of oxygen is called oxidative phosphorylation.
Chemiosmosis	The coupling reaction in which synthesis of ATP molecule takes during movement of H^+ across an H^+ gradient is called

	chemiosmosis.
Respiratory substrate	The organic substances of the cells used up in the respiratory process are called respiratory substrate.
Respiratory quotient	The ratio of the volume of carbon dioxide give out to the volume of oxygen absorbed (CO_2/O_2) is called the respiratory quotient.

MODEL SUBJECTIVE QUESTIONS

1. **What is respiration? Give its evolution.**
2. **Describe different steps of glycolysis.**
3. **Describe different steps of Krebs cycle.**
4. **Draw Krebs cycle.**
5. **Write note on electron transport chain.**
6. **Write note on respiratory substrate.**
7. **Write note on respiratory quotient.**

SHORT QUESTIONS

1. Define respiration.

Ans: The series of oxidation reduction reactions in which substances (glucose) are oxidized to carbon dioxide and oxygen and energy is released is called respiration.

3. Write name of enzymes involved in preparatory phase of glycolysis.

Ans: **hexokinase, phosphofructokinase, aldolase**

4. What is Krebs's cycle? Who did discover it?

Ans: Krebs cycle is a series of reactions in which the pyruvate from glycolysis is oxidized to CO_2. The Krebs cycle was discovered by Hans Krebs in the 1930s.

5. When does substrate level phosphorylation occur during Krebs cycle?

Ans: Substrate level phosphorylation occurs in this step 5. CoA is replaced by a phosphate group and **succinate** is formed. The phosphate group is then transferred to GDP.

6. What is electron transport chain?

Ans: The collection of electron carrier molecules embedded in the inner membrane of the mitochondrion is called electron transport chain.

7. What is oxidative phosphorylation?

Ans: The synthesis of ATP molecule in the presence of oxygen is called oxidative phosphorylation.

8. Define chemiosmosis.

Ans: The coupling reaction in which synthesis of ATP molecule takes during movement of H^+ across an H^+ gradient is called chemiosmosis.

9. What is Lactic acid fermentation?

Ans: The NADH reduces the Pyruvate to form lactic acid. This reaction occurs in the mammalian muscles and certain fungi. The animal used $NADH_2$ to reduce the pyruvate. This reaction is controlled by an enzyme **lactate dehydrogenase.**

10. What are Obligative anaerobic? Give example.

Ans: Obligative anaerobic organisms include certain types of bacteria. These organisms survive only in the complete absence of molecular oxygen. Its example is **clostridium** sp.

11. What are Facultative anaerobic?

Ans: Facultative anaerobic organisms and tissues include certain bacteria, yeasts, and cells. These organisms can ferment nutrients in absence of oxygen. It also generates some ATP. It also provides NAD for glycolysis.

12. What is respiratory quotient?

Ans: The ratio of the volume of carbon dioxide give out to the volume of oxygen absorbed (CO_2/O_2) is called the respiratory quotient.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. Number of CO_2 molecules used released during respiration.
(a) 2 (b) 5 (c) 6 (d) 1 ③

2 Net number of ATP produced during glycolysis:
[✓ (a) 2] (b) 3 (c) 5 (d) 6

3. Which of following causes breakdown of F- 6- P:
(a) Hexokinase (b) Glucokinase (c) Aldolase (d) Enolase

4. The name of glycolysis derives from the action of:
(a) Hexokinase (b) Glucokinase (c) Aldolase (d) Enolase

5. Number of ATP produced during investment phase of glycolysis is:
(a) 2 (b) 5 (c) 0 (d) 1

6. Number of ATP formed during oxidative phase of glycolysis:
(a) 2 (b) 3 (c) 6 (d) 4

7. The enzyme which causes change in position of phosphate is:
(a) Mutase (b) Glucokinase (c) Aldolase (d) Enolase

8. Number of NADH formed by the Krebs cycle of one molecules of glucose are:
(a) 2 (b) 3 (c) 6 (d) 4

9. Number of ATP formed by the Krebs cycle of one molecules of glucose are:
(a) 2 (b) 3 (c) 6 (d) 4

10. Number of FADH formed by the Krebs cycle of one molecules of glucose are:
(a) 2 (b) 3 (c) 6 (d) 4

11. FADH is formed during breaking of:
(a) Succinate [✓ (b) Succinyl CoA] (c) Fumarate (d) Malate

12. Oxaloacetate is formed during breaking of:
(a) Succinate (b) Succinyl CoA (c) Fumarate [✓ (d) Malate]

13. Number of NADH formed during Krebs cycle of one acetyl CoA:
(a) 5 (b) 2 [✓ (c) 3] (d) 4

14. Number of ATP formed by oxidation of one molecules of glucose are:
(a) 24 (b) 65 (c) 34 [✓ (d) 36]

15. Respiratory Quotient for glucose is:
(a) 1 (b) 2 (c) 0.5 (d) 4

16 Respiratory Quotient for fats is:
(a) 1 (b) 2 (c) 0.5 (d) 0.7

15. Respiratory Quotient for organic acid is:
(a) 1 (b) 2 (c) 0.5 (d) 4

Answers: 1. (c) 2. (a) 3. (c) 4. (c) 5. (c) 6. (d) 7. (a) 8. (c) 9. (a) 10. (a) 11. (b) 12. (d) 13. (c) 14. (d) 15. (a)

Fill in blanks

1. The series of oxidation reduction reactions in which substances (glucose) are oxidized to carbon dioxide and oxygen and energy is released is called __________.
2. Glucose enters the cell. It is phosphorylated by the enzyme __________.
3. _______ cycle is a series of reactions in which pyruvate from glycolysis is oxidized to CO_2.
4. The Krebs cycle was discovered by ________ in the 1930s.
5. The collection of electron ________ molecules embedded in mitochondrion.
6. Synthesis of ATP molecule in presence of oxygen is called ___________ phosphorylation.
7. The ________ particles contain an ATP synthase enzyme.
8. The NADH reduces _______ to form lactic acid.
9. Ratio of volume of carbon dioxide give out to volume of oxygen (CO_2/O_2) is called _______.
10. CoA is replaced by a phosphate group and _______ is formed.
11. Electrons are removed from food during _______ and the Krebs cycle.
12. The _______ has a prosthetic group called mononucleotide (FMN).
13. The iron protein then passes the electrons to a compound _______.
14. $FADH_2$ adds its electrons to transport chain at a lower energy level than that of ____.
15. The electron transport chain makes no _______ directly.
16. Mitochondria synthesize ATP during a mechanism called _______.
17. The F_1 particles contain an ATP ________ enzyme.
18. ______cycle is a series of reactions in which the pyruvate from glycolysis is oxidized to CO_2.
19. ________is first changed in Acetyl CoA. The Acetyl CoA then enters into the Krebs cycle.

Ans

1. Respiration 2. Hexokinase 3. Krebs 4. Hans Krebs 5. carrier 6. Oxidative 7. F_1 8. Pyruvate 9. respiratory Quotient 10. succinate 11. Glycolysis 12. Flavoprotein 13. ubiquinone, 14. NADH, 15. ATP16. chemiosmosis 17. Synthase, 18. Krebs 19. Pyruvate

True/False

1. Six-carbon glucose molecule is broken down into two molecules pyruvate during glycolysis.
2. Each molecule of glucose produces four molecules of ATP during glycolysis.
3. Glucose enters the cell. It is phosphorylated by the enzyme enterokinase.
4. An enzyme pyruvate kinase transfers the phosphate group from PEP to ADP.
5. ETC cycle is a series of reactions in which the pyruvate from glycolysis is oxidized to CO_2.
6. Pyruvate is first changed in Acetyl CoA. The Acetyl CoA then enters into the Krebs cycle.
7. CoA is replaced by a phosphate group and succinate is formed.
8. ATP are removed from food during glycolysis and the Krebs cycle.
9. The flavoprotein has a prosthetic group called mononucleotide (FMN).
10. The iron protein then passes the electrons to a compound ubiquinone.
11. $NADH_2$ adds its electrons to transport chain at a lower energy level than that of NADH.
12. The electron transport chain makes no ATP directly.
13. Mitochondria synthesize ATP during a mechanism called chemiosmosis.
14. Synthesis of ATP molecule in the presence of oxygen is called photo phosphorylation.
15. The F_1 particles contain an ATP synthase enzyme.
16. The respiration which takes place in absence of oxygen is called anaerobic respiration.
17. The value of respiratory quotient for fats is 2.0.

Ans: 1. T, 2. T, 3. F. hexokinase 4. T, 5. F. Krebs, 6. T, 7. T, 8. F. Electrons, 9. T, 10. T, 11. F. $FADH_2$, 12. T, 13. T. 14. F. oxidative, 15. T, 16. T, 17. F. 0.7

Chapter 7

NITROGEN METABOLISM

Syllabus
Biological nitrogen fixation

BIOLOGICAL NITROGEN FIXATION

The synthesis of organic nitrogenous compounds from atmospheric nitrogen by certain microorganisms is called biological nitrogen fixation. Higher plants cannot directly utilize molecular nitrogen of the atmosphere. But certain micro-organisms can utilize atmospheric nitrogen. There are two types of nitrogen fixing micro-organisms: Asymbiotic and symbiotic.

(a) ASYMBIOTIC NITROGEN FIXATION

The free living nitrogen fixing organisms are called are **asymbiotic** organisms. There are following organisms which fix the atmospheric nitrogen.

1. Aerobic bacteria and anaerobic bacteria

They are saprophytic organisms. Therefore, they fix nitrogen only in the soil. This soil must have good supply of organic manure. The example of anaerobic bacteria is **Clostridium** and the example of aerobic bacteria is **Azotobacter.**

2. Blue green algae (Cyanobacteria)

Blue green algae are autotrophic photosynthetic organisms. They grow in waterlogged and wet soil like paddy (rice) fields. Members of families Nostocales and Stigonematales are important nitrogen fixture. Some of its examples are:

(a) **Anabaena** is an important member. It consists of branched filaments. These filaments are made up of two types of cells

- **Green photosynthetic cells:** They fix the atmospheric carbon dioxide and release oxygen during photosynthesis.
- **Heterocyst:** They are slightly enlarged colourless cells. These are non-photosynthetic. They can fix atmospheric nitrogen aerobically. Some of the blue green algae do not have heterocysts. But they can fix nitrogen. Their mechanism is not understood.

(b) **Blue green algae living in higher plants:** The blue-green algae are free living in the soil. Some blue green algae enter into the tissues of higher plants. They permanently live inside. For example Nostoc lives in the mucilage cavities of Anthoceras. Some anabaena lives in the leaf cavities of the water fern. The nitrogen fixing ability of the blue green algae increases in higher plants. They produce more number of heterocysts. Nitrogenous substances regularly pass from the alga to the higher plant and carbohydrates pass from plant to cyanobacteria. Therefore, it may be called a symbiotic association.

(c) **Lichens:** Nostoc and Scytonema develops symbiotic association with fungi. This association is called lichens. The algal components fix the molecular nitrogen in the form of organic compounds.

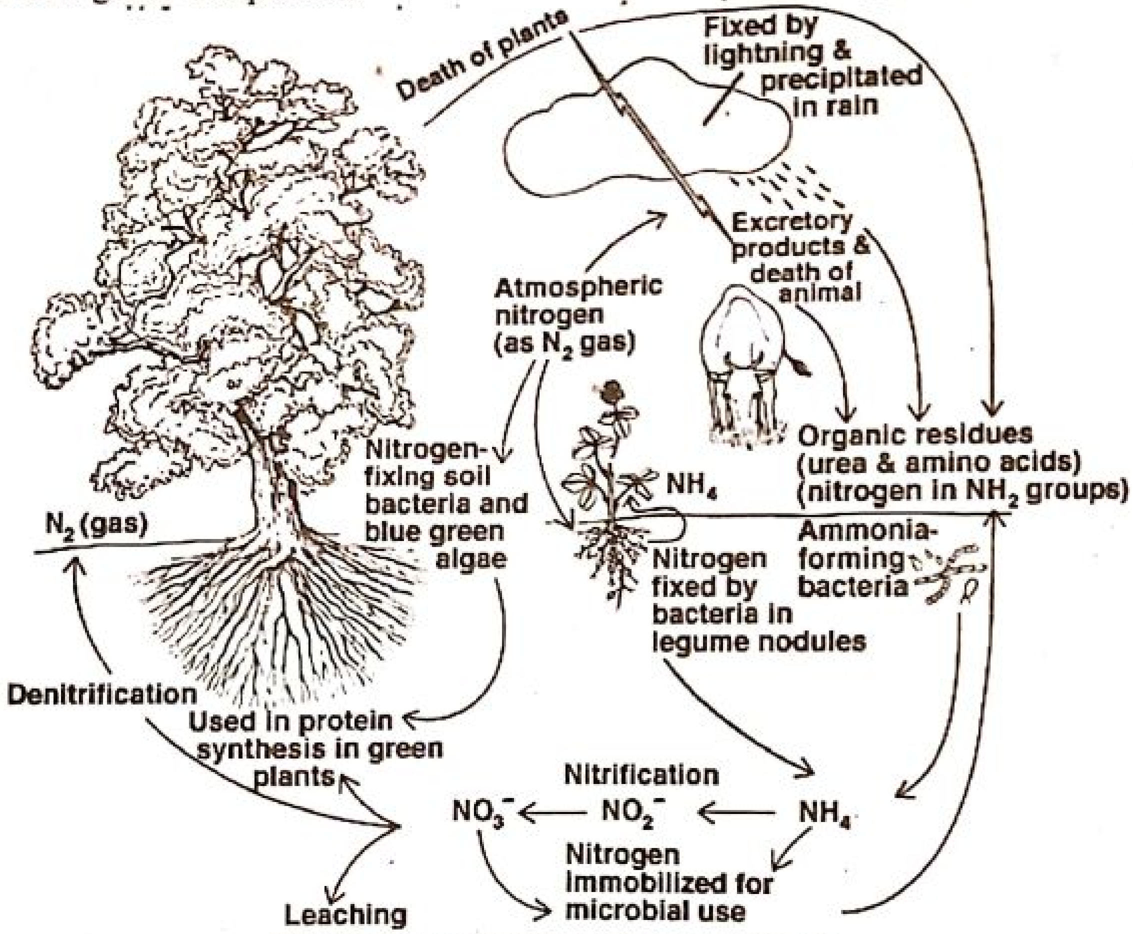

Death of plants
Fixed by lightning & precipitated in rain
Excretory products & death of animal
Atmospheric nitrogen (as N_2 gas)
Nitrogen-fixing soil bacteria and blue green algae
NH_4
Organic residues (urea & amino acids) (nitrogen in NH_2 groups)
N_2 (gas)
Ammonia-forming bacteria
Nitrogen fixed by bacteria in legume nodules
Denitrification
Used in protein synthesis in green plants
Nitrification
NO_3^-
NO_2^-
NH_4
Nitrogen immobilized for microbial use
Leaching

Fig: Nitrogen fixation (An over view)

(b) SYMBIOTIC NITROGEN FIXATION

It is the most important method of nitrogen fixation. These are of two types:

1. Fungi (Actinomycetes)

Several species of **Actinomycetes** develop mycorrhizal association with the root of Casurina, Pinus and other plants. These mycorrhizae may be ectotropic and endotropic mycorrhizae. These fungi have ability to fix atmospheric nitrogen.

2. Nodule forming Rhizobium species

It is most important nitrogen fixation. Its mechanism is fully known. A large number of leguminous plants like bean, pea, gram and soybean develop root nodules. All the plants of family Papilionacae develop nodules. 30 per cent of the species belongs to Caesalpinacae.

Leguminous plants increase the soil fertility. German Bacteriologist, Beijerinck identified that Rhizobium infect the root system and they develop nodules.

Bacteria mainly fix atmospheric nitrogen in the form of amino acids. These amino acids are transported by transpiration stream to different parts of the plant. In turn, bacteria get their food (carbohydrates) from the legume plant. Therefore, this relationship is symbiosis. The nodules are not formed on the root system without bacteria. Similarly bacteria themselves can fix atmospheric nitrogen.

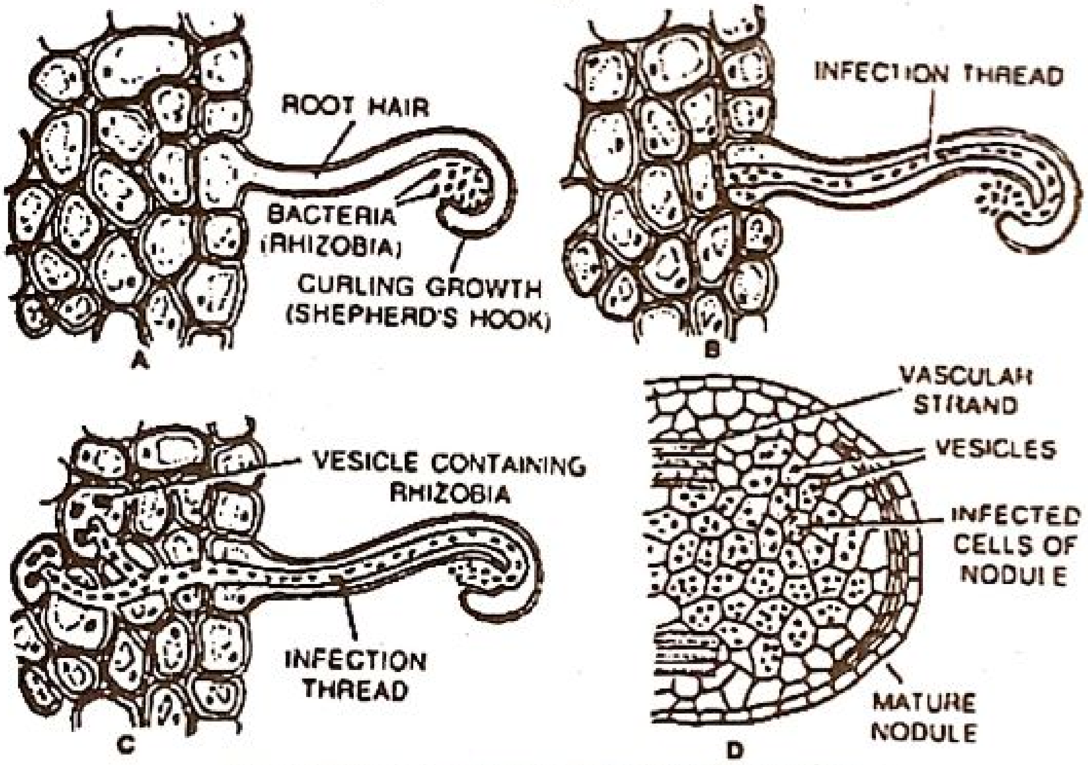


Fig: Different stages of nodule formation

Process of nodule formation

Nodules are formed by following process:

1. **Infection thread formation:** Nodule causing bacteria are present in the soil. The root system of leguminous plants secretes some sugars and amino acids. It attracts the bacteria. The bacteria multiply near the root zone. They develop a sufficient bacterial population. Then they infect the root hairs. A number of changes take place in the root hair cell. Cytoplasmic streaming movement increases. The nucleus of the root hair become doubles in size. The cell wall loosened. The plasmalemma invaginates and engulfs the bacterium. The root hair becomes curled. The bacterium becomes threadlike inside the root hair. This is called **infection thread.**
2. **Formation of nodule:** The infection thread becomes branched. These branches grow from one cell to the adjacent cell. They extend up to the inner cortical cells of the root. The cortical cells now start dividing rapidly. The growth substances auxins and cytokinins are secreted by the bacteria. These substances stimulate this cell division. Thus a tumor like structure appears on the root. It is known as **nodule.**
3. **Bacterioids formation:** The nodule grows and increases in size. The vascular tissues of the root extend to the tip of the nodule. The bacteria multiply rapidly in the host

cell of the root nodule. The infection threads are changed into globular oval cells. These are known as **bacterioids**. Nitrogen fixation is carried out in the bacterioids.

4. **Leghaemoglobin formation:** The nodule is pink in colour. The pink colour is due to the presence of pigment **leghaemoglobin.** This pigment is synthesized by the host cells in response to bacterial infection. It is similar to haemoglobin of red blood cells of mammals. As it is present in leguminous plants, so it is called leghaemoglobin.

   Significance of Leghaemoglobin:

   This is very important pigment. The ability of nitrogen fixation depends upon contents of this pigment. Older nodules lose this pigment. They become green or brown. They fail to fix nitrogen.

   Leghaemoglobin is an oxygen carrier. Thus oxygen becomes available for rapid respiration and ATP is synthesized in the nodule. Nitrogen fixation is a reductive process. It requires a large amount of energy. Respiration supplies this energy. The leghaemoglobin supply oxygen for respiration.

MECHANISM OF BIOLOGICAL NITROGEN FIXATION

Following reactions take place during biological nitrogen fixation:

1. Formation of ammonia

Nitrogen is reduced to ammonia in the bacterioids as follows:

$$N_2 + 8e^- + 16ATP + 8H \longrightarrow 2NH_3 + H_2 + 16ADP$$

Enzyme **nitrogenase** controls this reaction. This enzyme contains two metallic components molybdenum and iron. This reaction is not so simple. Several intermediate compounds are formed. But such compounds are not stable. Therefore, they are not clearly identified. **Diamide ($NH = NH$)** and **hydrazine** ($NH_2—NH_2$) and **$NH_3 – NH_3$** are the intermediate compounds. They are formed during formation of ammonia. Hydrogen for the reaction is donated by $NADH_2$. Respiration provides energy.

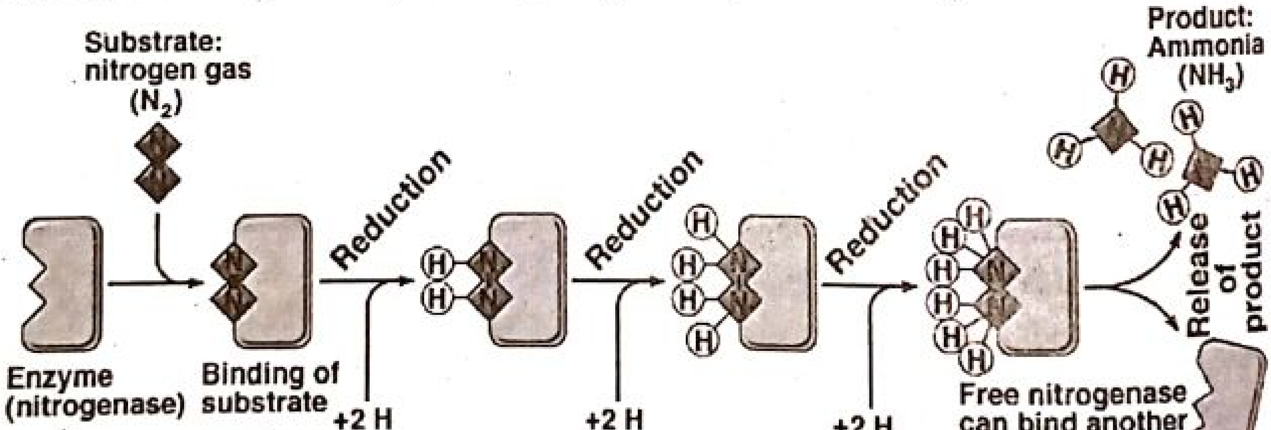


Fig: Functioning of enzyme nitrogenase

Action and significance of nitrogenase

The enzyme nitrogenase inactivated in the presence of oxygen. Therefore, enzymatic reduction of nitrogen to ammonia takes place in different site of the cell. Respiration occurs in different sites. These two sites are separated by compartment. Thus nitrogen reduction occurs in the bacterioids under anaerobic conditions.

Higher plants lack enzyme nitrogenase. This enzyme is provided by bacteria. Therefore, higher plants cannot fix molecular nitrogen without bacteria. However, genes of this enzyme are injected into higher plant by genetic engineering. Therefore, some transgenic plants can fix atmospheric nitrogen without bacteria.

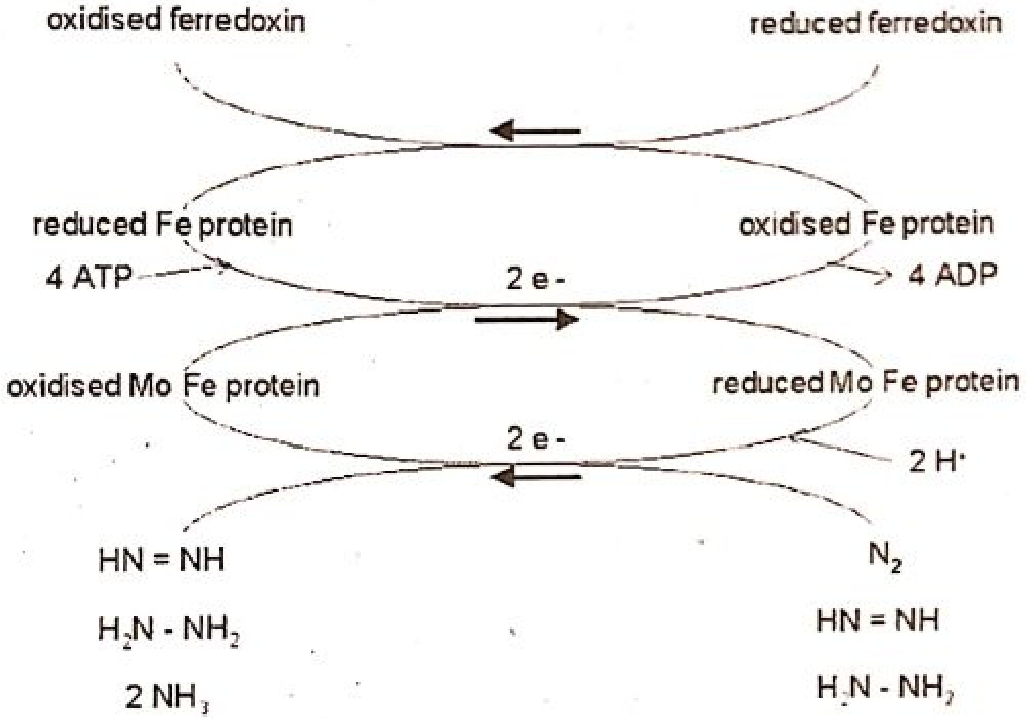


Fig: Different steps of nitrogen fixation by enzyme nitrogenase

2. Reduction of Ammonia to Nitrate

Most of the plants uses nitrate as principle source of nitrogen. Only few plants utilize ammonia directly for formation of nitrogenous compounds. Bacteria convert ammonia to nitrate by the process of nitrification. Nitrates are absorbed through roots of the plants.

3. Reduction of Nitrates back to Ammonium in plant cells

Nitrates cannot be directly used for the synthesis of other compounds like amino acids. Therefore, nitrates are converted back to ammonia. This process occurs in cytosol. It has following steps:

- Firstly nitrates are converted into nitrites. An enzyme **nitrate reductase** is responsible for this conversion. Here electrons are donated by NADH.

$$NO_3^- + NADH + H^+ + 2e^- \longrightarrow NO_2 + NAD^+ + H_2O$$

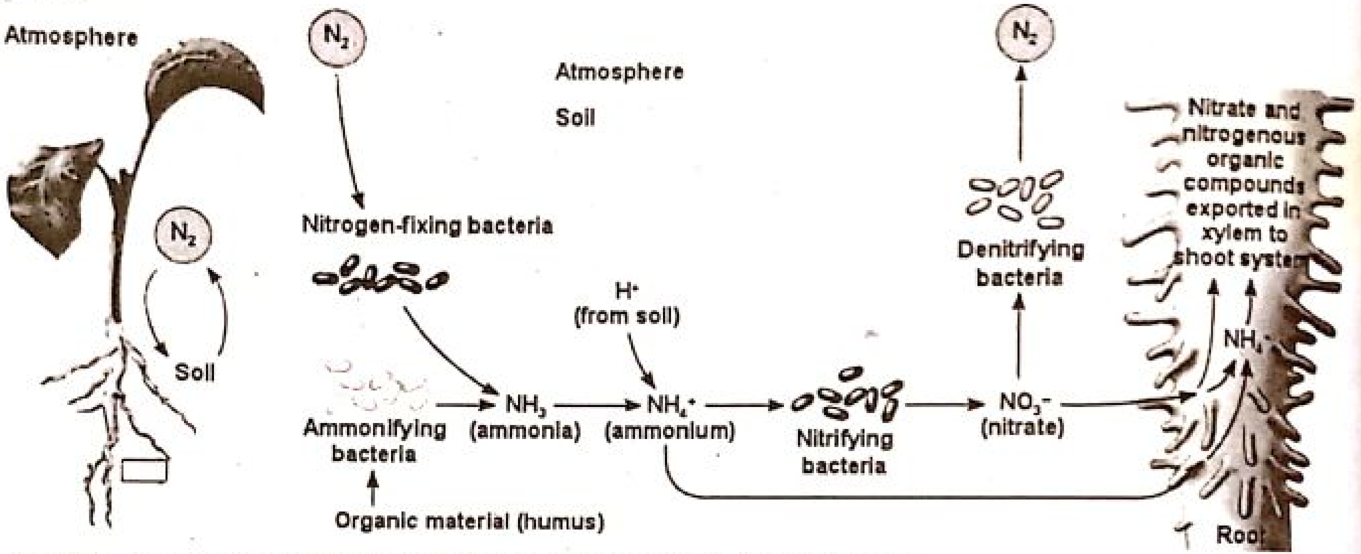
- Nitrites are then transferred to chloroplast. An enzyme **nitrite reductase** reduces nitrites to ammonia in chloroplast. Here ferrodoxin (Fd) is the electron donor.

$$NO_2 + 6Fd_{(red)} + 8H^+ + 6e^- \longrightarrow NH_4^+ + 6Fd_{(ox)} + 2H_2O$$

4. Synthesis of amino acids from ammonia

(a) Direct conversion of ammonia to amino acids in bacteria

Ammonia molecules are formed in nodule of bacteria. Some of this ammonia is directly incorporated into organic acids like α- ketoglutaric acid. They form glutamic acid. The- ketoglutaric acid is an intermediate of respiratory cycle. Glutamic acid is amino acids. Other amino acids are synthesized by transamination. Some of the amino acids are utilized by the bacteria for their growth. Other amino acids are translocated to the host plant.



(b) Synthesis of amino acids from ammonia in host plants

In most of the cases, ammonia is absorbed by host plants in the form of nitrates form its roots. It is then converted into nitrites in cytosol. Nitrites are then transferred to chloroplast. Nitrates are then again converted back to ammonia. This ammonia is used in the synthesis of different organic compounds in the host plant. Different reactions are involved in it:

- In first reaction, reductive amination of α- ketoglutaric acid occur. It produces glutamic acid. Enzyme, **glutamate dehydrogenase** catalyzes this reaction.

$$\alpha\text{- ketoglutaric acid} + \text{NaDH} + NH_3 \longrightarrow \text{Glutamic acid} + NAD^+ + H_2O$$

- In second reaction, glutamic acid reacts with ammonia in the presence of ATP. It forms glutamine. Enzyme **glutamine synthetase** catalyzes this reaction.

$$\text{Glutamic acid} + NH_3 + \text{ATP} \longrightarrow \text{Glutamine} + \text{ADP} + \text{Pi}$$

- Glutamine can be converted back into glutamic acid. Enzyme glutamate synthetase catalyzes this reaction.

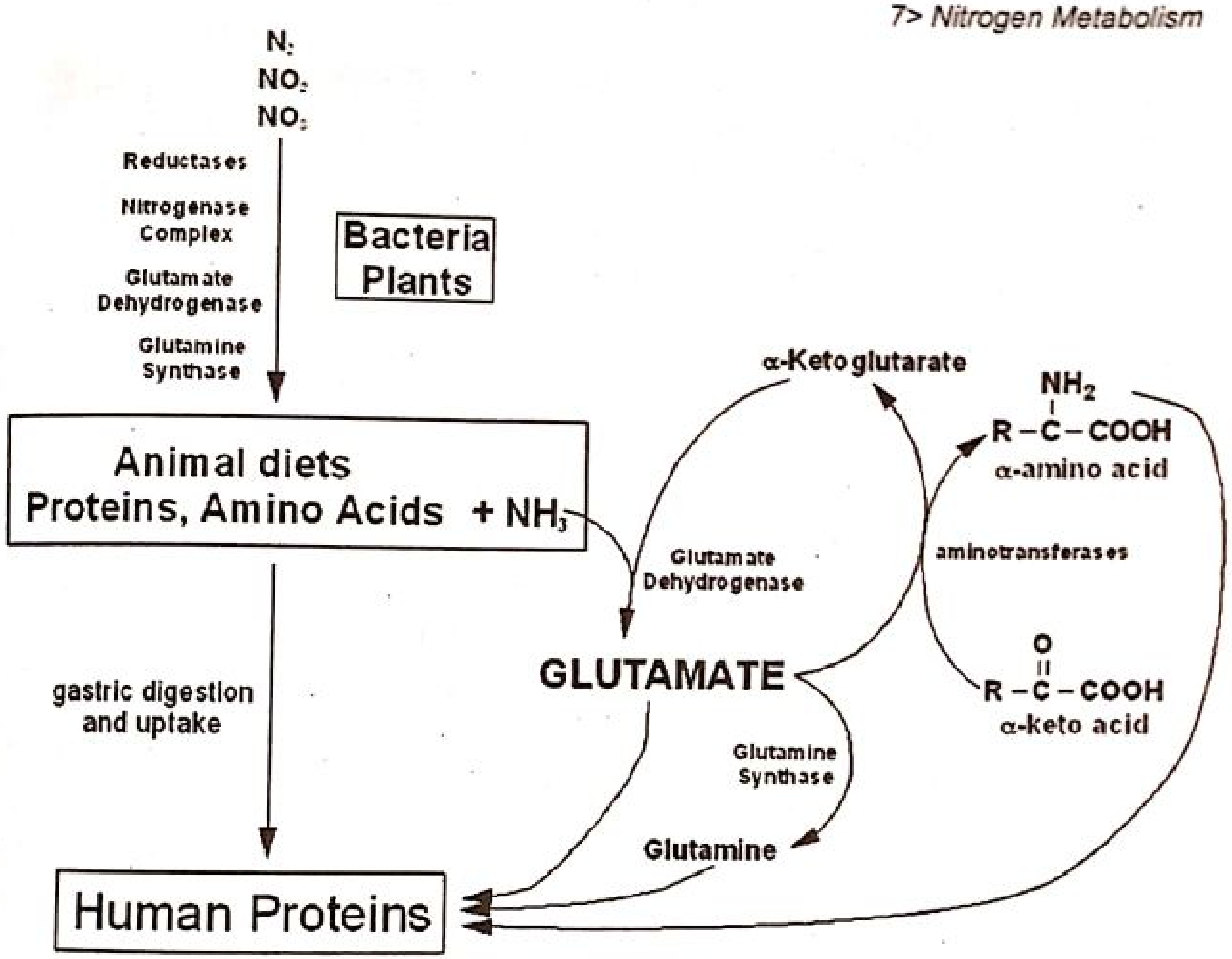
$$\alpha\text{- ketoglutaric acid} + \text{Glutamine} \longrightarrow 2\ \text{Glutamic acid}$$

5. Transamination processes

Glutamic acid is a precursor compound. Many other amino acids can be prepared from it by transamination processes. Enzymes aminotransferases catalyze these reactions.

$$\text{Glutamic acid} + \text{Oxaloacetic acid} \longrightarrow \text{Aspartic acid} + \alpha\text{- ketoglutaric acid}$$

Glutamic acid and aspartic acid temporarily store ammonia. They give rise further amino acids.



Process of amino acid synthesis in bacteria and plants

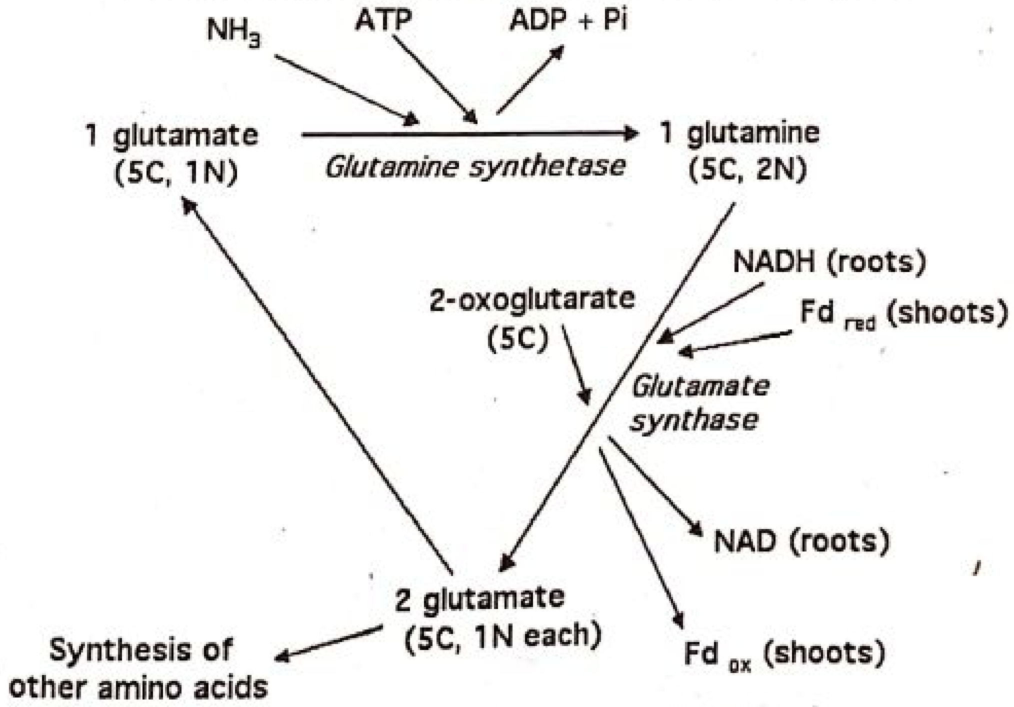


Fig: Glutamate or glutamic acid synthesis

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Nitrogen fixation	The synthesis of organic nitrogenous compounds from atmospheric nitrogen by certain microorganisms is called biological nitrogen fixation.
Asymbiotic organism	The free living nitrogen fixing organisms are called are asymbiotic organisms.
Leghaemoglobin	The nodule is pink in colour. The pink colour is due to the presence of pigment leghaemoglobin.

MODEL SUBJECTIVE QUESTIONS

1. **Write note biological nitrogen fixation.**
2. **Give mechanism of biological nitrogen fixation.**
3. **Write note on symbiotic bacteria.**

SHORT QUESTIONS

1. **Define biological nitrogen fixation.**

Ans: The synthesis of organic nitrogenous compounds from atmospheric nitrogen by certain microorganisms is called biological nitrogen fixation.

2. **Why do plant need fixation of atmospheric nitrogen?**

Ans: Higher plants cannot directly utilize molecular nitrogen of the atmosphere. But certain micro-organisms can utilize atmospheric nitrogen. There are two types of nitrogen fixing micro-organisms: Asymbiotic and symbiotic.

3. **What is role of lichens in biological nitrogen fixation?**

Ans: Nostoc and Scytonema develops symbiotic association with fungi. This association is called lichens. The algal components fix the molecular nitrogen in the form of organic compounds.

4. **What is the role of fungi in biological nitrogen fixation?**

Ans: Several species of **Actinomycetes** develop mycorrhizal association with the root of Casurina, Pinus and other plants. These mycorrhizae may be ectotropic and endotropic mycorrhizae. These fungi have ability to fix atmospheric nitrogen.

5. **What is leghaemoglobin?**

Ans: The nodule is pink in colour. The pink colour is due to the presence of pigment **leghaemoglobin.** This pigment is synthesized by the host cells in response to bacterial infection. It is similar to haemoglobin of red blood cells of mammals.

6. **Which intermediate compound is formed during biological nitrogen fixation?**

Ans: Diamide ($NH = NH$) and hydrazine ($NH_2—NH_2$) and $NH_3 – NH_3$ are the intermediate compounds.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. **Which of the followings is an anaerobic bacterium?**

(a) Azotobacter (b) Nitrobactor (c) Clostridium (d) None

2. Which of the followings is non-aerobic bacterium?

(a) Azotobacter (b) Nitrobactor (c) Clostridium (d) None

3. Which of the followings fixed nitrogen in waterlogged soil?

(a) Nostoc (b) Nitrobactor (c) Clostridium (d) None

4. Which of the followings is a group of biological nitrogen fixing group of fungi?

(a) Nostacles (b) Actinomycetes (c) Casurina (d) None

5. The nodule forming bacteria are:

(a) Azotobacter (b) Nitrobactor (c) Clostridium (d) Rhizobium

6. Percentage of specie of Caesalpinacae involved in biological nitrogen fixation are:

(a) 10 (b) 30 (c) 50 (d) All

Answers: 1. (c) 2. (a) 3. (a) 4. (b) 5. (c) 6. (b)

Fill in blanks

1. The free living nitrogen fixing organisms are called are _________ organisms.
2. Several species of _________ develop mycorrhizal association with the root plants.
3. Diamide and _________ $(NH_2—NH_2)$ and $NH_3 - NH_3$ are the intermediate compounds.
4. The enzyme nitrogenase inactivated in the presence of ________. Therefore, enzymatic reduction of nitrogen to ammonia takes place in different site of the cell.
5. Higher plants lack enzyme _______for nitrogen fixation, provided by bacteria.
6. Some transgenic plants can fix atmospheric nitrogen without ________.
7. In most of cases, ammonia is absorbed by host plants in the form of ________ form its roots.
8. In first reaction, reductive amination of α- ketoglutaric acid occur. It produces glutamic acid. Enzyme, glutamate ___________ catalyzes this reaction.
9. In most of cases, ammonia is absorbed by host plants in the form of _______ form its roots.
10. The enzyme _________ inactivated in the presence of oxygen.
11. _______ infect the root system and they develop nodules
12. Nostoc lives in the mucilage cavities of______.
13. Enzyme nitrogenase contains two metallic components molybdenum and ______.

Ans 1. Asymbiotic 2. Actinomycetes 3. Hydrazine 4. Oxygen 5. nitrogenase 6. bacteria 7. nitrates 8. dehydrogenase 9. nitrates, 10. nitrogenase, 11. Rhizobium, 12. Anthoceras 13. iron

True/False

1. Higher plants cannot directly utilize molecular nitrogen of the atmosphere.
2. There are two types of nitrogen fixing micro-organisms: Asymbiotic and symbiotic.
3. The example of anaerobic bacteria is azobactor.
4. Bacteria live in the mucilage cavities of Anthoceras.
5. A large number of leguminous plants like bean, pea, gram and soybean develop root nodules.
6. Rhizobium infect the root system and they develop nodules.
7. The pink colour of root nodule is due to the presence of pigment chlorophyll.
8. Enzyme nitrogenase controls this reaction. This enzyme contains two metallic components molybdenum and iron.
9. The enzyme nitrogenase inactivated in the presence of CO_2..
10. Higher plants lack enzyme nitrogenase. This enzyme is provided by bacteria.
11. In most of the cases, ammonia is absorbed by host plants of urea form its roots.

Answers: 1. T, 2. T, 3 F. Clostridium, 4. F. Nostoc, 5. T, 6. T, 7. F. leghaemoglobin 8. T, 9. F. oxygen, 10. T, 11. F. nitrates

Chapter 8

GROWTH & PLANT HORMONES

Syllabus
1. Definition
2. Role of auxins, gibberellins, cytokinins, abscisic acid and ethylene in controlling growth
3. Introduction to plant tissue culture

GROWTH

The quantitative increase in plant body is called growth. Following processes are involved in the growth and development of plants:

a) Cell division
b) Cell elongation
c) Differentiation of cells into tissues and then organs.

Growth is an irreversible increase in size and development. It is a programmed series of stages from a simpler to more complex form. As development proceeds, cellular differentiation of structure and function takes place.

The plants have a growth pattern called **open growth**. The plant adds new organs such as branches, leaves and roots throughout the life. Plant enlarges its body from the tips of roots and shoots. But the rate of growth is not uniform throughout the plant body. The growth is slow at the beginning. But gradually it becomes rapid and attains a maximum rate. Then gradually it slows down.

Meristems

The growth occurs through the activity of meristems in vascular plants. **Meristems are young tissues or group of cells that retain the potential to divide.** The entire plant body is capable of growing in lower plants. On the hand, the entire plant body is not capable of growing in higher plants. Their growth is limited to certain regions known as **growing points**. These growing points consist of groups of cells which are capable of division. These growing points are called **meristem**. These meristematic cells are located at the stem and root. There are following types of meristems:

1. **Apical Meristems: The meristems present at the tips of roots and shoot are called apical meristems.** They are primarily concerned with the extension of plant body. The perpetual growth zones are present at the apices of roots and stems. They increase the number of cells at the tips of roots and stem. Thus they play important role in primary growth.

2. **Intercalary Meristems: The meristem situated at the bases of internodes is called intercalary meristem.** These are the parts of apical meristem. They get separated from apex meristem by permanent tissues. They play important role in the production of leaves and flower. These are of temporary nature.
3. **Lateral Meristems: The cylinders of dividing cells present in the vascular and cork tissue of the plants are called lateral meristems.** Lateral meristems are present in dicots and gymnosperms. Vascular and cork cambium are the example of lateral meristem. They play an important role in the increase in diameter of stem and root. So they are involved in secondary growth.

There are two types of lateral meristem:

(a) **Determinate:** Their growth is determinate i.e. they grow to certain size and then stop. For example leaves, flowers and fruits

(b) **Indeterminate:** Their growth is indeterminate i.e. they grow by meristems that continually replenish themselves during remaining youthful age. For example, vegetative root and stem.

Types of Growth

Growth is of two types:

(a) **Primary Growth:** In this growth, primary tissues are added by the apical meristem. It increases the length of the plant.

(b) **Secondary Growth:** In this growth, secondary tissues are added by the intercalary or vascular cambium. It increases the thickness of plant.

Phases of Growth

Growth of multicellular plant is divided into four phases, cell division, elongation, maturation and differentiation.

1. Phase of Cell division

The numbers of cells are increased by mitosis during this phase. It occurs at the tip of root and shoot. These cells are small and they have spherical nuclei lying in the center of cytoplasm. So they are non-vacuolated. After the cell division each daughter enlarges in size. Synthesis of cytoplasm and cell wall material also takes place in this zone.

2. Phase of cell elongation

The zone of elongation is present a little distance from apex of root and shoot. It is only of few millimeters in length. The cells uptake of water during elongation and their volume increases up to 150 fold. Plasticity of the cell wall increases and wall pressure is reduced. Synthesis of new cytoplasm and cell wall material remain continue.

3. Phase of differentiation and maturation

The cell attains its final size during maturation. The cells of pith, cortex and certain other tissues do not elongate further along the axis. While other cells like fibers and tracheids elongate lengthwise more than in other direction. The walls of many kinds of cells and tissues become pitted. Thickening appears on the walls of xylem vessels.

The cells of various tissues differ in spatial dimensions and many new structural features develop in them.

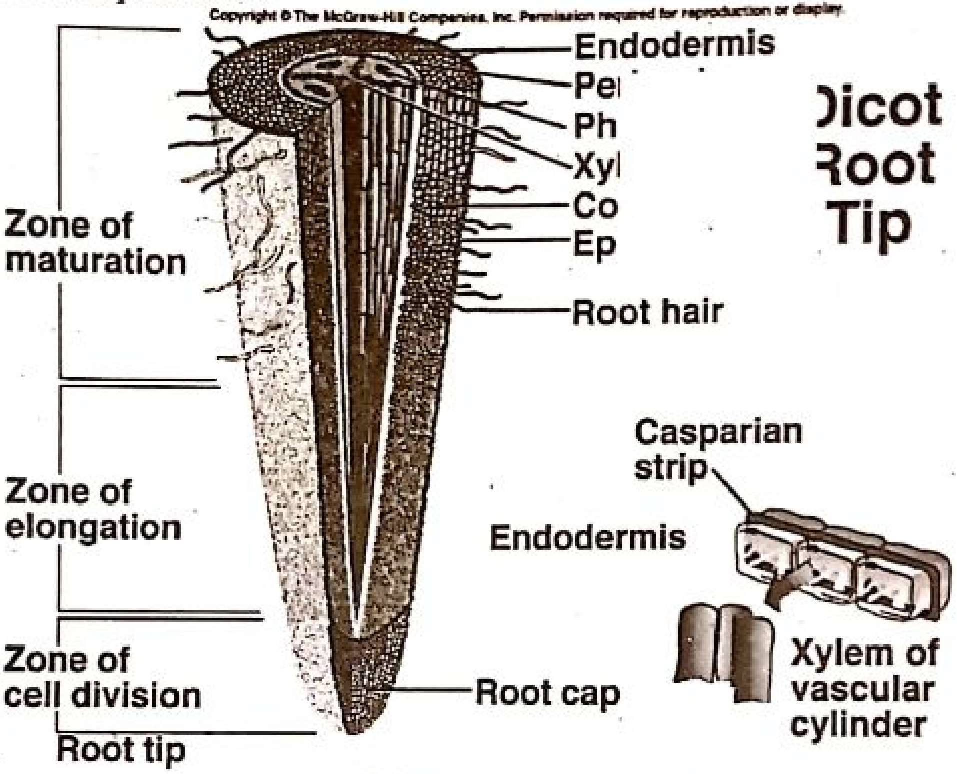


Fig: Phase of growth

PLANT HORMONES

The special substances produced by the plants which influence the growth and plant responses are called plant hormones. Plant hormones are also called **phytochromes** or plant growth substance. The term phytohormone was used by Thimann in 1948. Plant hormones are signal molecules. In animals, glands produce and secrete hormones. But glands are absent in plant. In plants, each cell is capable of producing hormones. They are produced within the plant. They occur in extremely low concentrations.

Functions of plant hormones

Plant hormones perform following functions in plants:

1. Hormones regulate cellular processes in targeted cells locally. They may move to other locations, in other functional parts of the plant.
2. Hormones also determine formation of flowers, stems, leaves and shedding of leaves.
3. Plant hormones shape the plant.
4. They affect the seed growth.
5. The control the time of flowering.
6. They also control the sex of flowers.
7. They may regulate senescence of leaves, and fruits.
8. They affect which tissues grow upward and which grow downward.
9. The affect on leaf formation and stem growth.
10. They also regulate development and ripening of fruit.

11. They affect plant longevity and even plant death.
12. Hormones are vital to plant growth. Without hormones, plants will be mostly a mass of undifferentiated cells. So they are also known as growth factors or growth hormones.

Classification of plants hormones

Plant hormones can be classified into two categories: growth stimulators and growth inhibitors.

(a) Growth Stimulators

The hormones which stimulate and promote growth in plants are called growth stimutators. Auxins, gibberellins and cytokinins are growth stimulator hormones. These hormones promote process involved in plant growth and development. They activate the plants for performing normal activities. These hormones promote cell division cell elongation, flowering, setting and ripening of fruits. They mostly delay leaf and fruit senescence. They are also involved in phototropism and geotropism.

(b) Growth Inhibitors

The hormones which inhibit growth and antagonize growth stimulators are called growth inhibitors. Abscissic acid (ABA) and ethylene are growth inhibitor hormones. Abscissic acid inhibit cell division and cell elongation. Thus it inhibits growth. These hormones promote bud and seed dormancy. They stimulate the closure of stomata. They promote leaf and fruit senescence.

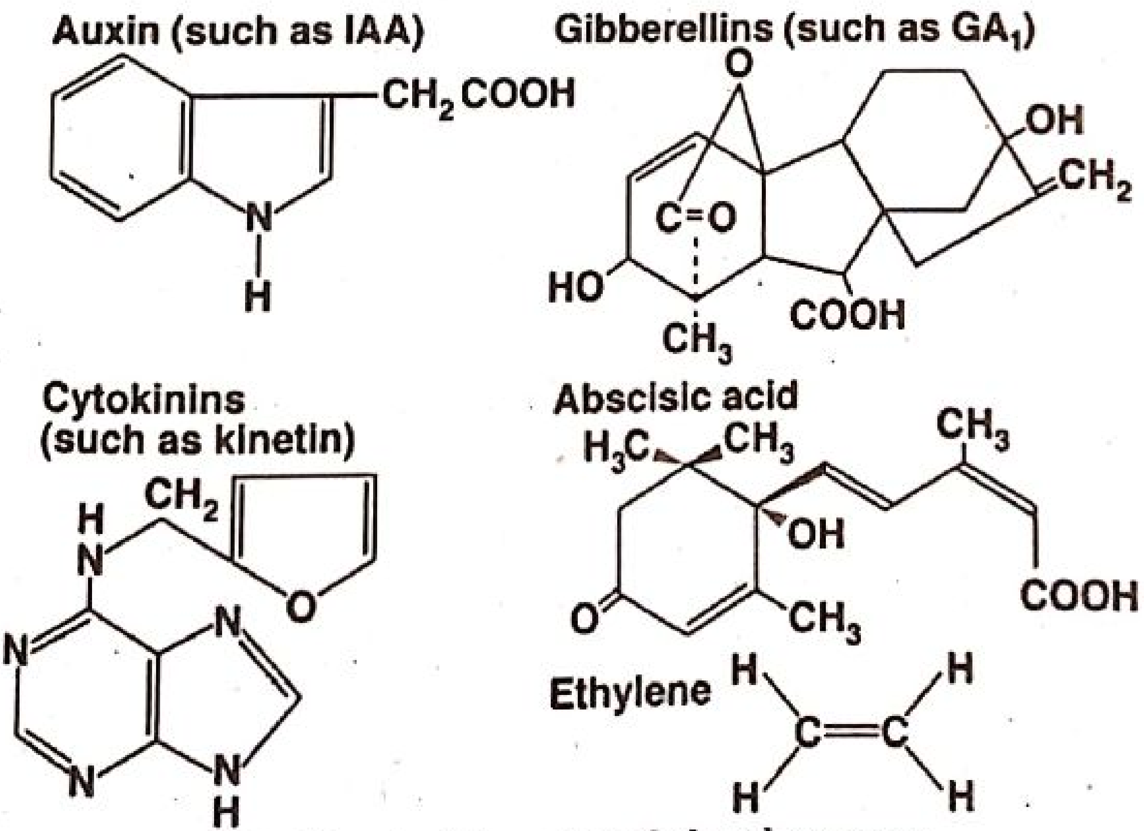


Fig: Chemical formulas of plant hormones

AUXINS

Name of auxins derive from the Greek word **auxein** means to grow/increase. The natural auxins are **indole acetic acid (IAA).** Auxins and their role in plant growth were first described by Dutch scientist Frits Warmolt Went. Kenneth V. Thimann isolated this hormone. He determined its chemical structure as indole-3-acetic acid (IAA).

Discovery of Auxins (Not included in B.Sc. Syllabus)

Following scientists played their role in the discovery of auxins

1. Charles Darwin

Charles Darwin and his son performed experiments on coleoptiles in 1881. Coleoptiles are sheaths. These sheaths enclose young leaves in germinating grass seedlings. Darwin exposed the coleoptile to light from a unidirectional source. He observed that they bend towards the light. He covered various parts of the coleoptiles with a cap. Thus Darwin discovered that light is detected by the coleoptile tip. But that bending occurs in the hypocotyl. The seedlings did not bend towards light if the tip was covered with cap or if the tip was removed. Darwin concluded that the tip of the coleoptile was responsible for sensing light. He proposed that a messenger is transmitted in a downward direction from the tip of the coleoptile. It causes bending of seedling.

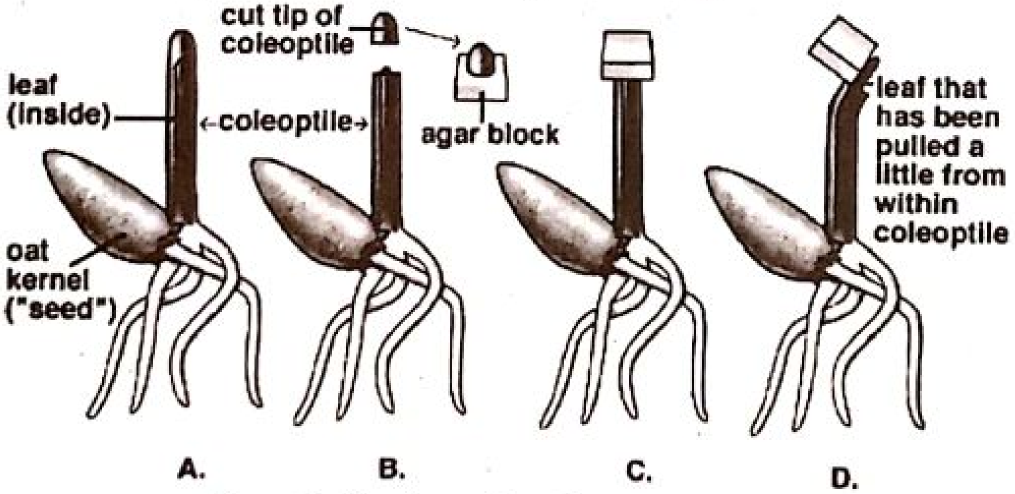


Fig: Application of auxin on coleoptile

2. Peter Boysen-Jensen

Peter Boysen-Jensen was a Danish scientist. In 1913, he demonstrated that the signal was not fixed. It was mobile. He separated the tip from the remainder of the coleoptile by a cube of gelatin. This cube prevented cellular contact. But it allowed chemicals to pass through. The seedlings responded normally. Thus it bent towards the light. Then he separated the tip by an impermeable substance. Now stem did not bend.

3. Frits Went

Frits Warmolt was Dutch botanist. He performed experiments in 1926 on coleoptile. He showed that a chemical messenger diffuses from coleoptile tips. He studied the effects of growth promoting chemical. He also studied how coleoptile grows towards light.

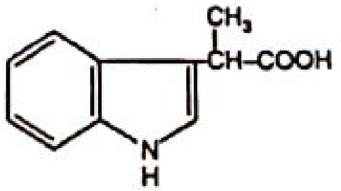
1. Went cut the tips of the coleoptiles. He placed them in the darkness.

2. He put a few tips on agar blocks. Agar block absorb the growth-promoting chemical.
3. He took one control coleoptiles. He placed a block on it that lacked the chemical.
4. On others, he placed blocks containing the chemical. He placed the chemical in centre or on top of the coleoptile. It distributed the chemical evenly or increased the concentration on one side.
5. In first case, growth promoting chemical was distributed evenly. Now the coleoptile grew straight. In second case, the chemical was distributed unevenly, the coleoptile curved away from the side with the cube. It grows towards light.
6. Went proposed that the messenger substance is a growth-promoting hormone. He named it **auxin**. Auxin becomes asymmetrically distributed in the bending region.
7. Went concluded that auxin is at a higher concentration on the shaded side. Now it promotes cell elongation. Thus a coleoptiles bending towards the light.

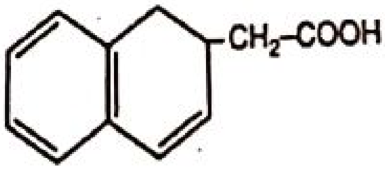
Chemical nature of Auxins

There are two forms of auxins. These are auxin a and auxin b. Chemically, auxin a is auxentriolic acid ($C_{18}H_{32}O_5$). But auxin b is auxeniolonic acid ($C_{18}H_{30}O_4$). But auxin a and b are hardly known In plants. **Heteroauxin** is the principal naturally occurring hormone in higher plants. It is chemically IAA ($C_{10}H_{902}N$). In addition to IAA, several other related compounds and derivatives are found in plants. Some of these are:

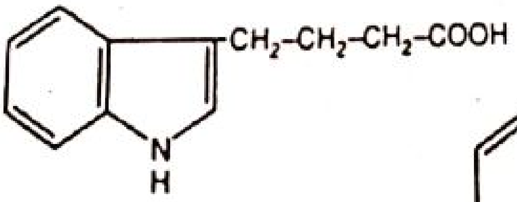
a) Indolebutric acid (IBA)
b) Indole 3 acetaldehyde
c) Indole - 3 ethanol,
d) 4 Chloro IAA



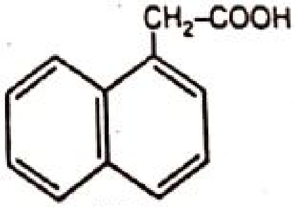
α-Indole propionic acid (IPA)



β-NAA



α-Indolebutyric acid (IBA)



α-NAA

Synthetic auxins

A large number of synthetic auxins are present. These synthetic auxins are more effective than natural auxins. The important synthetic auxins are:

a) **Indole butyric acid (IBA)**
b) **Naphthalene acetic acid (NAA)**
c) **2,4-dichlorophenoxyacetic acid (2,4-D)**
d) **Para chlorophenoxy acetic acid**

ROLE OF AUXINS IN PLANT GROWTH (PHYSIOLOGICAL ROLE)

Auxins play following roles in plant growth:

1. Coleoptile and Stem Growth

Auxin was discovered in coleoptile. It causes growth of the coleoptile of wheat, maize and other cereals. The tip of coleoptile produces auxin. Therefore, coleoptile shows rapid growth. When the tip is removed, the growth of the coleoptile stump stops. Auxin causes growth of the coleoptile by cell elongation. It also causes growth in stem by cell elongation.

2. Cell Elongation

Auxin causes loosening of cell wall. The rigid cell wall becomes soft and its plasticity increases. The loosening of cell walk decreases the wall pressure (WP) or turgor pressure (TP). So cell absorbs more water. It increases the size of vacuole. As a result the cell stretches and elongates.

3. Secondary Growth

It is found that the tip of sunflower seedlings produces auxin. This auxin causes secondary growth. If this tip is removed, secondary growth also stops. Auxin stimulates the formation of secondary vascular cambium. Therefore, auxin controls secondary growth or thickness of the stem.

4. Rooting of Cuttings

Stem cuttings of some plants like rose form adventitious roots at their basal end in the moist soil. The leaves and buds on the cutting promote the rooting. These leaves and buds produce auxin. The application of auxin promotes rooting of stem cuttings. Synthetic auxins like IDA and NAA are more effective.

Thus auxins are widely used to induce rooting in vegetative propagation of fruit and ornamental plants. However, auxins fail to cause root formation in a few species like guava, mango, Eucalyptus and others.

5. Apical Dominance

The phenomenon in which shoot apex inhibits the growth of lateral buds is called apical dominance. The terminal bud produces auxins. It inhibits the growth of lateral bud. Therefore, the main stem continues to grow. If the tip is cut off, the influence of the apex on the lateral buds is lost. Now lateral buds emerge and form branches.

Auxin alone is not responsible for apical dominance. Other hormones like cytokinin and gibberellin are also involved in apical dominance.

6. Sex Expression

Auxins change the sex ratio in some plants. The flowers of some plants like cucumber and ridge gourd are unisexual. But both male and female flowers are borne on the same plant (Monoecious). These plants produce a large number of male flowers. But it produces only a few female flowers. Application of auxin increases the number of female flowers and decreases the number of male flowers.

In dioecious species like Cannabis, genetically male plants produce exclusively male flowers. It starts producing female flowers with the application of auxin. Here the effect of auxin is indirect. Auxin produces another hormone ethylene. Ethylene changes the sex ratio of flowers and develops more female flowers.

7. Parthenocarpy

The phenomenon in which ovary changes into fruit without fertilization is called parthenocarpy. The production of auxin increases in ovary after pollination. The endosperm produces auxin in the ovule. This auxin changes ovary into fruit. The flower falls or withers without pollination. The application of auxin develops the fruit without pollination and fertilization in some plants like tomato and brinjal. It is parthenocarpy. Parthenocarpic fruits are seedless. Some fruits like banana and orange are naturally parthenocarpic. Their ovary has high concentration of auxin even before pollination. This auxin develops their ovary into the fruit.

8. Abscission

The falling of leaves, flowers and fruits is called abscission. The green lamina of young leaves produce auxin. This auxin prevents the abscission of leaves. The old leaves cannot produce sufficient auxin. So they fall. If auxin is applied on such leaves, abscission is prevented. Similarly, application of auxin prevents abscission of flowers and fruits. The NAA and 2, 4-D are used commercially to prevent premature fall of immature citrus and apple fruits.

The cell of the abscission layer secretes hydrolytic enzymes like cellulase and pectinase. These enzymes dissolve the cell wall. The organ detaches at this point and falls. Auxin inhibits the action of these enzymes and prevents abscission.

9. Tropism

The bending of plant organs like coleoptile, stem and root toward or away from stimulus due to unequal growth is called tropism. It may be phototropism if the stimulus is light. Or it may be geotropism if the stimulus is gravity. Auxin also controls phototropism and geotropism.

a) **Phototropism:** A stem is exposed to light from one side. One half of the stem receives the light. The other half is shaded. Auxin produced at the tip. It is transported downward. The lighted half of the stem gets about 35% of auxin. But the shaded side receives about 65 % of auxin. As a result, the shaded half of the stem grows more than the lighted half. It bends the stem towards light.

b) **Geotropism:** A coleoptile is placed horizontally. The lower half of the coleoptile possesses more auxin than the upper half. Therefore, lower side grows more than the upper side. It bends the coleoptile upward.

Commercial applications of Auxins

The chemists have synthesized many synthetic auxins. The synthetic auxins are economical to produce than IAA. The plants do not have enzymes to break down these synthetic auxins. So synthetic auxins are more active than the natural auxins.

Synthetic Auxins	Functions
(a) NAA (Naphthalene acetic acid) **(b)Indole propionic acid**	**1.** They stimulate fruiting and help in natural fruit set. **2.** Sometimes, they cause fruit setting in absence of pollination (**parthenocarpy**)
2,4 D (2,4 Dichloro phenoxy acetic acid)	**1.** It is selective weed killer. It kills broad leaved species (dicot). It is used in cereal crops and lawns to eliminate weeds. **2.** It inhibits sprouting of potatoes. **3.** It prevents premature fruit drop (retard abscission)

GIBBERELLINS

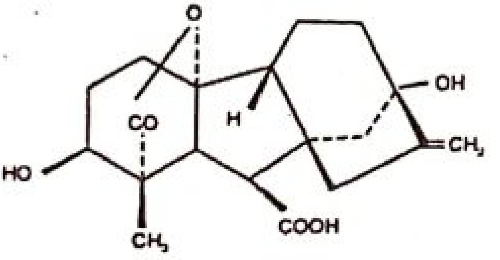
Gibberellins (GAs) are plant hormones that regulate growth various developmental processes. These process include stem elongation, germination, dormancy, flowering, sex expression, enzyme induction, and leaf and fruit senescence.

Discovery

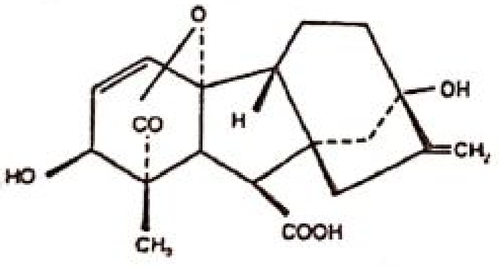
Gibberellin was discovered by Kurosawa in 1928. He observed that a rice plant was infected by the fungus **Gibberella**. It showed excessive stem elongation. The symptom is called **Bakanae** disease. The fungus produces a substance .This substance caused this elongation. This substance was named **gibberellin** after the name of this fungus.

Types

Gibberellin occurs in algae, fungi, liverworts and higher plants. 62 different types of gibberellins have been discovered. These are abbreviated as GA and are serially numbered from GA_1 to GA_{62}. The most commonly occurring gibberellin is GA_3. It is also called **gibberellic acid**. Gibberellic acid was the first gibberellin to be discovered.

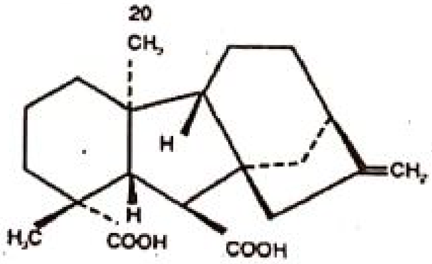


Gibberellin A_1 (GA_1)

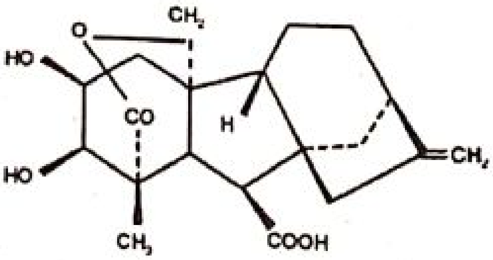


Gibberellic acid (GA_3)

(a) C_{19} – GAs



Gibberellin A_{12} (GA_{12})



Gibberellin A_{20} (GA_{20})

(b) C_{20} – GAs

Chemical nature

Gibberellins are **tetracyclic diterpene acids**. There are two classes based on the presence of either 19 or 20 carbons.

a) The 19-carbon gibberellins are like gibberellic acid. They have lost carbon 20. In its place, they possess a five-member lactone bridge. This bridge links carbons 4 and 10.

b) The 19-carbon forms are generally biologically active forms of gibberellins.

Hydroxylation also has a great effect on biological activity of gibberellin. In general, the most biologically active compounds are dihydroxylated gibberellins. It possesses hydroxyl groups on both carbon 3 and carbon 13. Gibberellic acid is a dihydroxylated gibberellin.

ROLE OF GIBBERELLINS IN PLANT GROWTH (PHYSIOLOGICAL ROLES)

Gibberellins play following physiological roles in plants

1. Seed Dormancy

The physiological inability of a seed to grow is called seed dormancy. Dormant seeds do not germinate even under favourable conditions of water, air and normal temperature. Gibberellic acid breaks the dormancy in some seeds

a) The seeds of lettuce requires stimulus of light. The requirement of light can be replaced by gibberellic acid. Therefore, gibberellin treated seeds can germinate in the dark.

b) The seeds of some temperate species like apple and peach need low temperature (1-7°C) for a few days. Gibberellic acid can replace the need of low temperature for seed germination.

2. Seed Germination

Gibberellin plays an important role in the germination of cereal grains like barley and wheat. The seed imbibes water. It releases gibberellins in the embryo. The gibberellin then moves to the aleurone cells of the endosperm. It stimulates the fresh synthesis of an enzyme called α-amylase. This enzyme hydrolyses starch into sugar. The embryo utilizes the sugar and develops into the seedling. The role of gibberellins in the germination of dicot plants is unknown.

Storage cells of the seed contain starch, proteins, fats and mineral nutrients. The young seedlings use these stored compounds for its germination. It continues to use compounds till it itself able to absorb these compounds by its roots. Gibberellins stimulate the breakdown of these compounds into sucrose and amino acids. GA stimulates the production of enzyme hydrolases. These enzymes digest the starch, proteins present in the endosperm. These digested compounds then can be transported easily. Thus seedling easily utilizes these simple compounds for its initial growth.

3. Stem Growth

The most important effect of gibberellin is on stem elongation. Application of gibberellin causes rapid stem elongation. It has great effect on two types of plants: genetic dwarfs and rosette plants.

(a) **Genetic dwarf:** The mutant strains of maize d_1 and d_5 remain dwarf. They do not grow beyond 1-2 feet. Such plants are unable to synthesize gibberellin. The internodes fail to elongate in the absence of gibberellin. Therefore, the stem remains dwarf. When gibberellic acid is given to these plants, the stem rapidly elongates. The plant acquires the height of normal tall varieties of maize.

(b) **Rosette dwarf: The plants with very short stem and crowed leaves are called rosette plant.** The stem is very short in carrot and radish. It is not more than a cm in length. Their leaves are crowded together in vegetative phase. Such a condensed disk like stem is called rosette stem. The rosette habit is due to deficiency of gibberellin. When gibberellic acid is applied to rosette plants of radish, the stem elongates. It grows to 3 - 4 feet tall. **The rapid stem elongation of rosette plant is called bolting.** Bolting also occurs in rosette plant naturally at the start of flowering. The plant itself produces large quantity of gibberellin at this time.

The deficiency of gibberellin inhibits of cell division at subapical meristem. Therefore, the stem remains very short at the internodes in the rosette plants. The application of gibberellin promotes cell divisions in the subapical meristem. Therefore, the stem elongates rapidly.

4. Rooting of Cuttings

Gibberellic acid inhibits the formation of adventitious roots on the stem cuttings. Therefore, it is antagonistic to auxin.

5. Flowering in Plants

Gibberellic acid causes flowering in two types of plants: rosette long day plants and vernalization requiring biennials.

(a) **Rosette long day plants:** Rosette plants like Hyoscyamus and Samolus remain vegetative under short days. But they produce flowers in long days. The application of gibberellin makes the plants to flower even under short days.

(b) **Vernalization requiring biennials:** Similarly carrot plant requires low temperature (vernalization) for flowering. The application of gibberellin overcomes this requirement. Now the plants can flower without exposing to low temperature.

6. Sex Expression

The application of gibberellin increases the number of male flowers in many plants like cucumber, ridge gourd and pumpkin. But it decreases the number of female flowers. Thus its affect is reverse to auxin. Female plants of Cannabis produce male flowers when gibberellin is applied. Therefore, GA changes the sex ratio of flowers towards maleness.

7. Fruit setting

The start of fruit growth after pollination is called fruit setting. The application of gibberellins cause fruit setting in many plants. Fruit set is stared in apple and grapes by the application of GA.

Commercial applications of gibberellins

Some of their commercial applications are as under.

1. **Fruiting:** GA promotes fruit setting in tangerines and pears. It is used for growing

seedless grapes, (parthenocarpy). GA increases the size of seedless grapes It also increases size of berry. Mixture of GA with other hormones improves the shape apple fruit.

2. **Increasing yields of sugar-cane:** GA stimulates elongation of internode during winter season. Therefore, it has more capacity of storing sucrose. Thus application of gibberellin can increase sugar yield by 2 tons per acre.
3. **Early formation of cones in Pinus:** GA_{4-7} stimulates the formation of cones on very young trees in Pinus. Thus application of GA reduces the time to seed production in it.
4. **Bolting in vegetables:** GA causes bolting in biennial vegetables like cabbage, beet etc. It reduces the time of seed production in these plants.
5. **Brewing industry:** GA_3 is used in the brewing industry. It stimulates α-amylase enzyme production in barley. α-amylase promotes malting.
6. **Increase of storage time of fruits:** It delays ripening of bananas. So it improves storage life of bananas and grape fruits. Gibberellins delay senescence in citrus fruits. Thus it increases storage time of citrus fruit.

CYTOKININS (CK)

Cytokinins (CK) are a class of plant hormones which promote cell division, or cytokinesis, in plant roots and shoots. They are involved primarily in cell growth and differentiation. But they also affect apical dominance, axillary bud growth, and leaf senescence. Folke Skoog discovered their effects using coconut milk in the 1940s

Discovery of Cytokinins

It has following history of discovery:

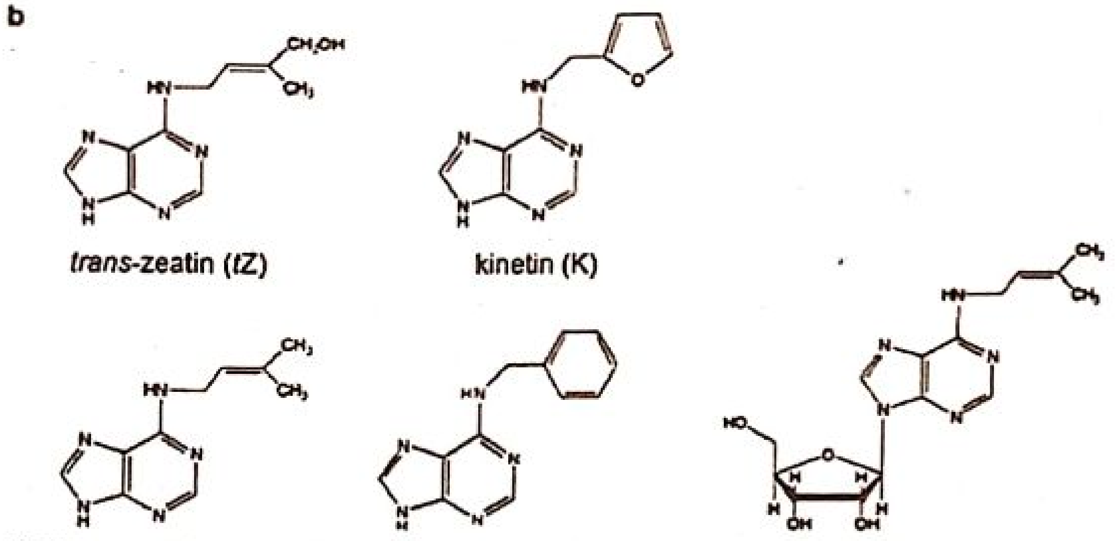
1. Earlier, it was believed that coconut milk contain cell division causing factors.
2. The developing endosperm of maize also contains such factors.
3. Later, herring (fish) sperm DNA was heated. It gives cell division causing factor. This substance can cause cell division in tobacco pith cells. It was named **kinetin**. But kinetin does not occur in any of the plants. It is only a degradation product of DNA.
4. **Letham** (1963) extracted, purified and crystallized such a hormone from the developing maize grain. This substance was named **zeatin**. Zeatin was found in many plants.
5. It was soon found that both kinetin and zeatin are similar in chemical structure. All such cell division causing substances are called cytokinins (cytokinesis cell division).
6. The chemists synthesized two very important cytokinins. One is **kinetin**. The other is **benzyladenine (BA)**.

Chemical nature of Cytokinins

There are two types of cytokinins:

a) Adenine-type cytokinins: Its examples are kinetin, zeatin and 6-benzylaminopurine. Most adenine-type cytokinins are synthesized in roots. Cambium and other actively dividing tissues also synthesize cytokinins. These cytokinins participate in local and long-distance signaling like purines and nucleosides.

b) Phenylurea-type cytokinins: These are like diphenylurea and thidiazuron (TDZ). No phenylurea cytokinins have been found in plants. These are provided exogenously.



trans-zeatin (*t*Z) kinetin (K)

N^6-[2-isopentyl]adenine (IP) N^6-benzyladenine (BA) N^6-Isopentenyladenosine (iPR)

ROLE OF CYTOKININS IN PLANT GROWTH (PHYSIOLOGICAL ROLES)

1. Control of Cell Cycle

Cell cycle includes DNA replication and mitosis. CK along with auxin control the cell cycle in many plants. Auxin regulates DNA synthesis. Cytokinins regulate to mitosis. For example, auxin initiates DNA synthesis in cultured tobacco tissue. But the cells do not divide. When they are provided with cytokinins they divide.

2. Cell Division

Tissue culture helped to understand the role of cytokinins in plants. Pith tissues were taken out from the stem of tobacco plant. They were supplied mineral salts, vitamins and sucrose in vitro. Pith cells do not grow on this medium. Auxin is added to the medium. But they do not divide and slightly enlarge. Then kinetin is added alone. The cells again do not divide. Then both auxin and kinetin were together put in the medium. Now the pith cells starts dividing rapidly by mitosis. It forms a lump of undifferentiated cells. **The lump of undifferentiated cells is known as callus.** Therefore, cytokinin causes cell division in tobacco pith cells in the presence of auxin.

3. Stimulation of Cell Enlargement

Cytokinin may promote cell enlargement in some seedlings of some dicot plants like sunflower, cucumber etc. This cell enlargement enlarge cotyledon during germination of seedling of these species. Application of Cytokinin promotes cell enlargement in cotyledon of seedling without increase in dry weight.

4. Morphogenesis

The differentiation of different tissues like root, shoot from callous is called morphogenesis. The ratio of cytokinins to auxin controls the morphogenesis.

(a) The cytokinin to auxin ratio is 10:1. It produces callus.

(b) This ratio was increased by increasing the concentration of auxin or decreasing the concentration of cytokinin (100:1). Now the cells organize themselves. They differentiated into numerous roots.

(c) Now the auxin to cytokinin ratio is decreased (1:1). A number of shoot buds are differentiated on the callus. These buds finally develop into tiny tobacco plants.

5. Delay of Leaf Senescence

The degradative changes which lead to death of an organ or organism are called leaf senescence. When a leaf becomes old, it becomes senescent. It dies or fails down. Proteins, chlorophyll and nucleic acids are broken down into simpler compounds during this process. They are broken into sugars, amino acids and other metabolites. These soluble substances are exported out of the leaf to the other plant parts. The leaf becomes **chlorotic.** It dries up or falls down. The application of cytokinin delays the senescence. Cytokinin maintains the level of metabolites. It prevents their degradation.

6. Role in Chloroplast Maturation

Dark-grown seedlings are etiolated. The etioplasts develop from proplastids in the absence of light. Etioplasts contain carotenoids. Thus they do not synthesize chlorophyll and structural proteins. These are required for formation of thylakoid system. The treatment of etiolated seedlings with cytokinin form chloroplasts. These chloroplasts have more extensive grana. CK also increases the rate of chlorophyll and photosynthetic enzymes synthesis. Thus cytokinins have role in chloroplast maturation.

7. Role in Apical dominance

Cytokinin is antagonistic to auxin. It releases the plant from apical dominance. It promotes the growth of lateral buds. Kinetin, benzyladenine and zeatin are used to promote growth of lateral bud.

Commercial applications of CK

1. Cytokinins delay aging of fresh leaf crops like cabbage and lettuce delay of senescence)
2. They keep the flowers fresh.
3. They can also be used to break dormancy of some seeds.

ABSCISIC ACID (ABA)

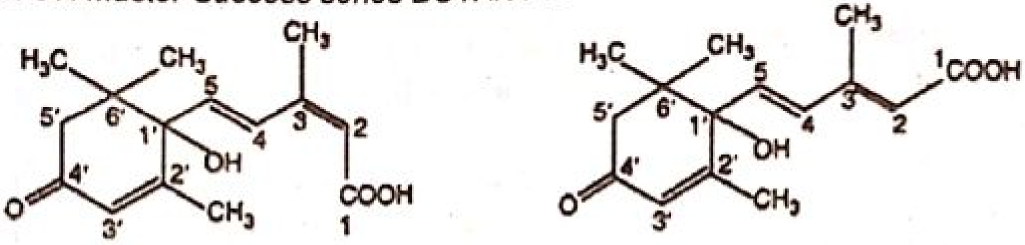
Abscisic acid (**ABA**) is also known as **abscisin II**. ABA is involved in abscission. ABA functions in many plant developmental processes, including bud dormancy.

Discovery

P.F. Wareing in U.K. and F.T. Addicott in USA in 1961 discovered growth inhibiting hormone. It was named **abscisic acid (ABA)**. Abscisic acid was discovered from the leaves of ***Acer pseudoplatanus*** and fruits of cotton plant. It exists universally in higher plants. It occurs in large amount in the fruits of Avocado and rose, dormant tubers of potato and seeds of apple.

Chemical nature

ABA is a naturally occurring compound in plants. Chemically, it is a sesquiterpenoid (15-carbon).



Cis-Abscisic acid
(Biologically active)

Trans-Abscisic acid
(Biologically inactive)

Fig. 17.29. Chemical structures of abscisic acid (ABA)

ROLE OF ABSCISIC ACID IN PLANT GROWTH (PHYSIOLOGICAL ROLES)

1. Growth inhibitor

ABA is growth inhibitor hormone. It inhibits the growth of root, stem, leaf and coleoptile. Even its very low concentration is effective. Gibberellin reverses the effect of ABA. Thus plant resumes normal growth. Therefore, abscisic acid and gibberellic acid have opposite effects on plants.

2. Role in apical dominance

ABA makes the apical bud dormant in temperate species like Betula, Morus and fig. The growth of shoot apical bud ceases. It is covered with scale leaves. These leaves are small, non-green and membranous.

3. Role in seed dormancy

ABA also makes the seeds of several species dormant. ABA inhibits the synthesis of hydrolytic enzymes. These enzymes are essential for the breakdown of storage food in the seeds. Thus nutrients are not available to seedling. Such seeds fail to germinate even under favourable conditions. Its affect can be reversed by the application of gibberellic acid.

4. Dormancy of bud

The shoot buds of temperate tree species become dormant in autumn season. Similarly, freshly harvested seeds of apple and peach do not germinate. The potato tubers fail to sprout soon after harvesting. All these are caused by accumulation of large amount of ABA in these organs. The concentration of ABA decreases and concentration of gibberellins increase in spring. Therefore, shoot buds sprout and the seeds start germinating in spring.

5. Effect of Drought

A large quantity of ABA accumulates in plant during drought or water deficiency. It has a biological advantage for the plant. It helps to withstand the effect of drought. Following changes help plants to resist drought:

a) ABA closes the stomata. It prevents further loss of water. Thus plant is able to conserve available moisture and withstand the drought.

b) In root ABA stimulates water flow and ion in to roots. Thus water influx enters into the roots. This water regulates turgor. Thus it prevents plant from wilting.

c) ABA increases ionic uptake in roots. It decreases resistance to flow of water. Thus there is increase in water potential gradient between the soil and the root. Therefore, available water can be easily absorbed.

d) ABA also induces root growth. It stimulates formation of lateral roots. It suppresses leaf growth. It reduces leaf area and increase in absorption area of roots. Thus water uptake is increased during condition of drought.

6. Promotion of abscission and senescence

ABA was originally found as abscission hormone. Application of ABA promotes the abscission of leaves, flowers and fruits. ABA promotes senescence. Actually ethylene causes abscission. ABA indirectly stimulates ethylene synthesis. Thus it stimulates abscission. ABA greatly accelerates the senescence.

7. Regulation of protein synthesis

ABA is also involved in certain protein synthesis. These proteins play role in certain conditions like heat shock and salt tolerance. Some of these proteins also help plant to adapt to cold temperatures.

8. Role in closing of stomata in condition of stress

ABA is a stress hormone. It is very helpful to plant in combating water stress condition. It closes the stomata to conserve water. Guard cells have specific ABA receptors. These receptors are present on the outer surfaces of their plasma membrane. ABA blocks the proton pump present in guard cell membrane. Thus guard cells lose turgid and become flaccid. It closes the stomata.

Commercial application of Abscisic acid

Abscisic acid is sprayed on tree crops. It regulates fruit drop at the end of the season. This removes the problems of picking fruits in a large time-span.

ETHYLENE

Smoke was used for ripening of bananas in old time. Later it was found that smoke contain ethylene. It was found that this gas is also produced by the plant. It controls a number of physiological processes. Ethylene is produced by bacteria, fungi and higher plants. All the parts of the plant produce ethylene. But ripening fruits and meristematic regions of the plant produce a large amount of ethylene. Ethylene is the only gaseous hormone in plants.

Ethylene is a colourless unsaturated hydrocarbon gas. It is lighter than air. It has unsaturated bond between the carbon atoms. These bonds are essential for the stimulation of biological activity.

Ethylene is synthesized in every living cell of the plant body. It moves by diffusion in all directions. It regularly escapes out of the plant body in large quantities. Carbon dioxide nullifies the effect of ethylene. Therefore, CO_2 is called **antiethylene**. Salts of heavy metals like silver nitrate also prevent ethylene action by absorbing this gas.

ROLE OF ETHYLENE IN PLANT GROWTH (PHYSIOLOGICAL ROLES)

1. Dormancy of seeds and buds

Application of ethylene breaks dormancy of seeds of several species. These seeds then start germination. It also overcomes dormancy of potato tuber and causes its sprouting. Ethylene also increases the rate of seed germination in several species.

2. Responses in dicot seedlings

Application of ethylene to dicot seedlings shows three distinct responses. These are

(i) Inhibition of seedling elongation
(ii) Increase in the diameter of stem.
(iii) Disturbance of normal geotropic ability of roots

3. Stem elongation in monocots

In most of plants, ethylene inhibits stem elongation. But it promotes stem elongation in several monocots like rice. Rice is grown well irrigated land. Plants of rice are kept submerged. Sometimes, it becomes anaerobic environments. It inhibits ethylene synthesis in roots. The stored ethylene in roots is diffused into waterlogged soil. Thus submerged rice plants stem get high ethylene concentrations. It increases stem elongation in its stem.

4. Leaf and flower senescence

Ethylene increases the rate of leaf and flower senescence. It causes etiolation of leaves.

5. Epinasty

The downward curvature of leaves occurring when upper side of the petiole grows faster than lower side is called epinasty. Application of ethylene to dicot seedlings causes drooping down of the leaves. The leaves are normally oriented in horizontal direction. They hang down. It is called epinasty. There is a greater growth of the petiole on the upper side in epinasty. Epinasty is induced by ethylene and high concentration of auxin. Actually, auxin induces synthesis of ethylene. This ethylene then stimulates epinasty. Tomato seedlings are especially sensitive to ethylene. The production of ethylene is increased in the shoot of tomatoes in waterlogged or anaerobic conditions. It causes epinasty in it roots.

6. Ripening of fruits

It is the most important effect of ethylene. The banana and apple are kept in storage for ripening. The rate of respiration of the fruit increases. It is called **climacteric respiration.** Such fruits are called **climacteric fruits**. The climacteric fruits release a large amount of ethylene in storage. Ethylene starts the climacteric respiration and ripening.

Application of ethylene promotes ripening of climacteric fruits in storage. A chemical called **Ethrel** is available in the liquid form. It can be sprayed on the plant. It enters the plant cells and breaks down and release ethylene.

7. Role in abscission

Abscission is the shedding of leaves, flowers, fruits and other parts of plants. Ethylene primarily regulates abscission process. Auxin is antagonistic to ethylene. Thus it suppresses the effect of ethylene. So auxin prevents the abscission. Ethylene decreases the activity of auxin. Low level of auxin promotes abscission. High ethylene levels stimulate the production of specific hydrolytic enzymes. These enzymes digest cell walls and promote abscission.

8. Hook forming and opening

Terminal portion of shoot apex of some seedlings become hook shaped. Hoop shape protects the tender apical meristem. Ethylene causes unequal growth in shoot apex. It cause opening and closing of hook. Outer side of shoot apex grows at faster rate than inner one. Therefore, the apex become hook shaped. Then rate of growth of its inner side increases. Now hook opens.

9. Formation of roots

High concentration of ethylene stimulates root formation in leaves, stems, and in other roots.

10. Flowering inhibition and stimulation

Ethylene inhibits flowering in most of species. But it induces flowering in some plants like pineapples. Thus it is used commercially for fruit set in pineapple. It also initiates flowering in mangoes.

11. Change of sex of flowers

Some plants are dioecious like dates. They have separate male and female flowers. Ethylene can change the sex of developing flowers. It promotes female flowers is in cucumber.

Commercial application of Ethylene

1. Ethylene induces flowering in pineapple.
2. It stimulates ripening of tomatoes and citrus fruit.
3. The commercial compound **ethephon** breaks down and releases ethylene in plants. It is applied on rubber plant. It stimulates the flow of latex in rubber plant. Ethephon is sprayed in aqueous solution. Ethephon speed up the fruit ripening process in many plants like mangoes, apples etc.
4. Ethylene accelerates abscission of flowers and fruits.
5. Ethephon promotes fruit thinning or fruit drop in cotton, cherries, and walnuts.
6. Ethylene is also used to promote female flowering in cucumber. It prevents self-pollination.
7. Inhibition of ethylene increase storage time of different fruits.

PLANT TISSUE CULTURE

The in vitro cultivation of any part of plant in nutrient medium is called tissue culture. Plant tissue culture is a collection of techniques used to maintain or grow plant cells, tissues or organs under sterile conditions on a nutrient culture medium. Plant tissue culture is widely used to produce clones of a plant. These plants are produced as micropropagation. Different techniques are used in plant tissue culture. These techniques have advantages over traditional methods of propagation.

Objective of plant tissue culture

There are following objectives of plant culture:

1. Production of exact copies of plants. These plants produce good flowers, fruits, or have other desirable traits.

2. To quickly produce mature plants.
3. The production of multiples of plants in the absence of seeds or necessary pollinators to produce seeds.
4. The regeneration of whole plants from genetically modified plant cells.
5. The production of plants in sterile containers. It reduces the chances of transmitting diseases, pests, and pathogens.
6. The production of plants from seeds which have low chances of germinating and growing.
7. To clean particular plants of viral and other infections. To quickly multiply these plants as **cleaned stock** for horticulture and agriculture.

Basis of plant tissue culture

Plant tissue culture relies on single principle. According to this principle, many plant cells have ability to regenerate a whole plant. It is called totipotency of plant cells. German botanist Gottlieb Haberlandt said in 1902 that plant cells are **totipotent.** Totipotent means each cell has the full genetic potential of the organism. Therefore a single cell can become a complete plant. In tissue culture single cells, plant cells without cell walls (protoplasts), pieces of leaves, stems or roots are used. They generate a new plant on culture media.

Different Tissue Culture Techniques

There are different techniques of tissue culture. Some of these are callus culture, anther culture, suspension culture, ovule culture, embryo culture protoplast culture and micropropagation.

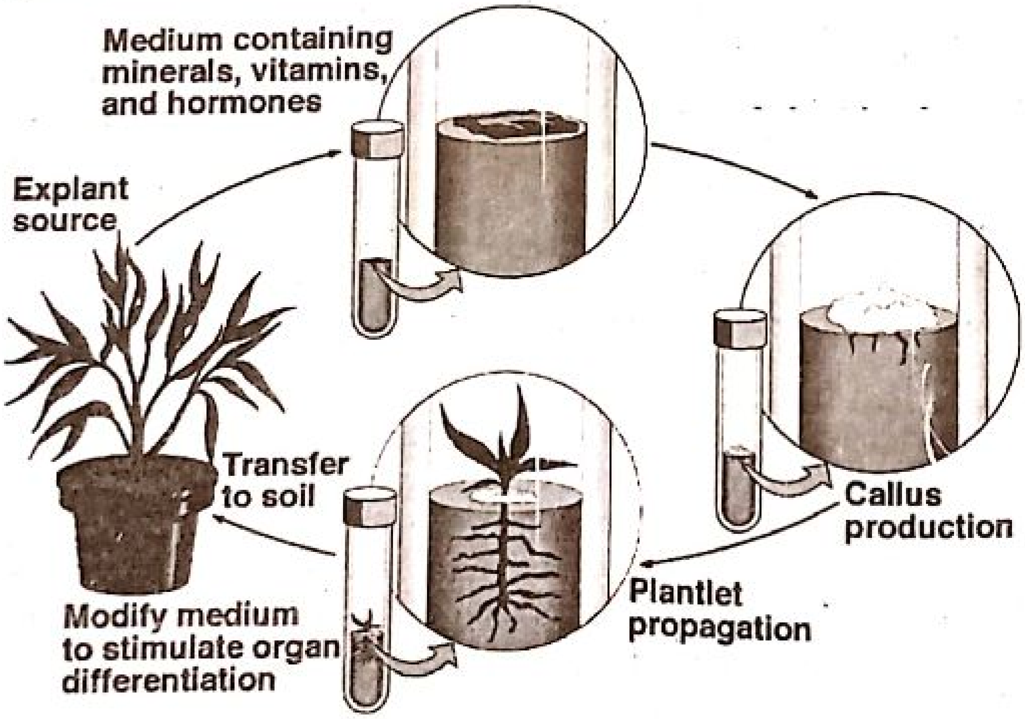

Medium containing minerals, vitamins, and hormones
Explant source
Callus production
Plantlet propagation
Transfer to soil
Modify medium to stimulate organ differentiation

Fig: Tissue culture: Callus culturing and plant propagation

1. Callus culturing

In 1958 Cornell botanist **F.C. Steward** grew a complete carrot plant from a tiny piece of phloem. He provided the cells with sugars, minerals, vitamins and coconut milk. Coconut milk contains the plant hormone cytokinins. The cultured cells began dividing, they produced a callus. **An undifferentiated group of cells is called callus.** Then the callus differentiated into shoot and roots and developed into complete plants.

Callus culturing provides genetic variability. The variations induced in plant through tissue culture are called **somaclonal variations.**

2. Meristem culture (Vegetative culturing)

It is latest commercial technique of tissue culture. Millions of identical seedlings can be produced by this technique in a limited space. The auxins and cytokinins are added the correct proportions in liquid medium. Many new shoots will develop from a single shoot tip. Each new shoot is removed. These shoots produce new plants. There are two advantages of meristem culture:

(a) The shoots are genetically identical to the adult plants. Thus the plants developed from them are called **clonal plants**. All the clonal plants have the same traits.

(b) Meristem is virus free. Therefore, the plants produced are also virus free. The presence of plant viruses weakens plants. Thus makes them less productive.

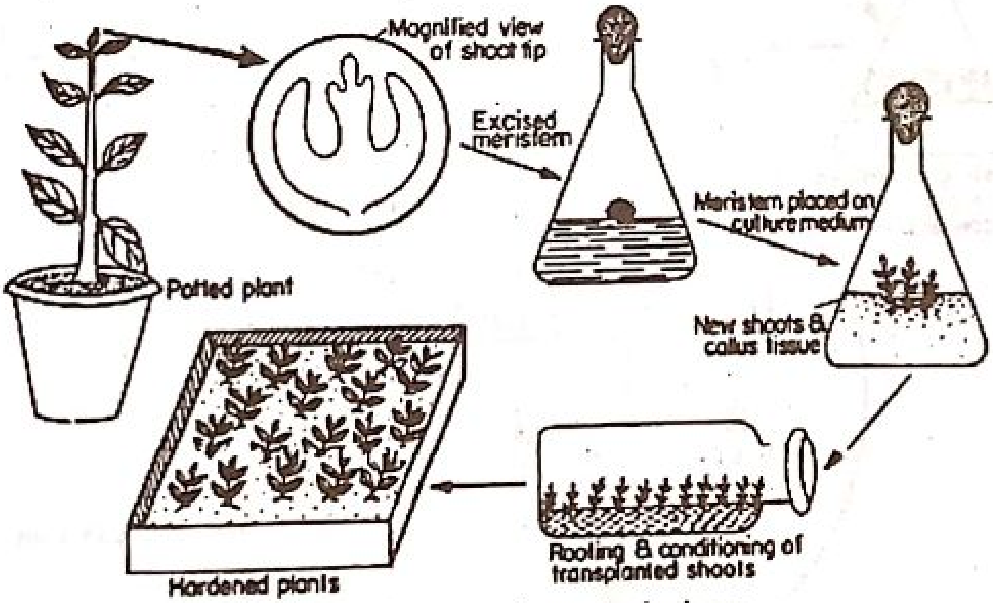

Magnified view of shoot tip
Excised meristem
Meristem placed on culture medium
Potted plant
New shoots & callus tissue
Hardened plants
Rooting & conditioning of transplanted shoots

Fig: Meristem culture technique

3. Micropropagation from a single cell and formation of somatic embryoes (Protoplast culture technique)

The plants are totipotent. Thus it is possible to grow an entire plant from a single cell. Following method is adopted in this technique:

(a) Enzymes are used to digest the cell walls of a small piece of tissue. These tissues are mesophyll tissue of a leaf. It produces naked cells without cell walls. It is called **protoplasts.**

(b) The protoplasts regenerate a new cell wall and begin to divide. This division forms clumps of cell.

(c) These **clumps** of cells are used to produce **somatic embryos.**

(d) Somatic embryos are covered in a protective hydrated gel. It is called **artificial seeds.**

Millions of somatic embryos can be produced at once in large tanks called **bioreactors**. This is done for certain vegetables like tomato, celery, and asparagus.

(e) A mature plant develops from each somatic embryo. Mutations can take place during the production of these plants. Therefore, the plants generated from the somatic embryo vary from each other. These are called **somaclonal variations**. These somaclonal variations can be used to produce new plants with desired traits.

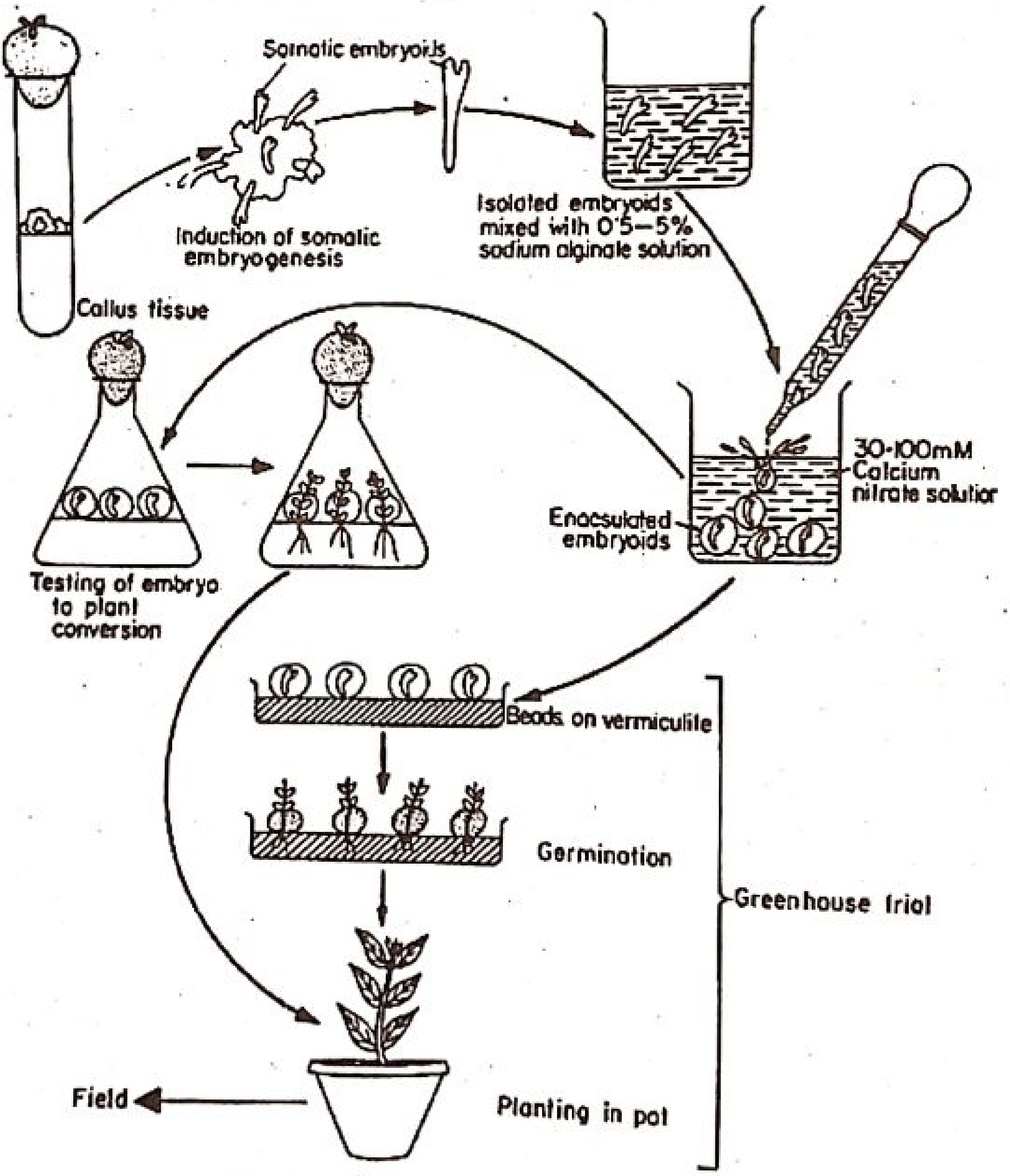

Somatic embryoids
Isolated embryoids mixed with 0·5—5% sodium alginate solution
Induction of somatic embryogenesis
Callus tissue
30-100mM Calcium nitrate solution
Encapsulated embryoids
Testing of embryo to plant conversion
Beads on vermiculite
Germination
Greenhouse trial
Field
Planting in pot

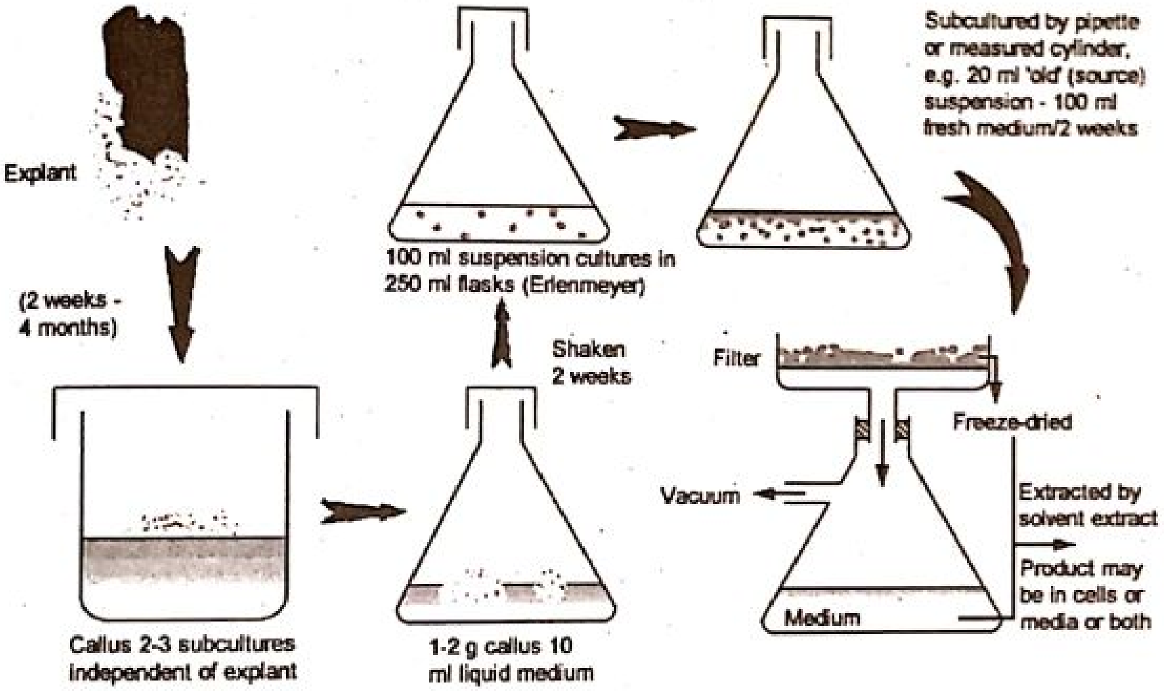
Fig: Formation of somatic embryos

4. Suspension culture

Rapidly growing cells are cut into small pieces. These pieces are shaken in a liquid nutrient medium. Thus single cells or small clumps of cells break off form a suspension. These cells will produce the same chemicals as the entire plant. For example:

(a) Cell suspension cultures of *Cinchona ledgeriana* produce **quinine**

(b) Cell suspension of ***Digitalis lanata*** produces **digitoxin.**


Explant
(2 weeks - 4 months)
Callus 2-3 subcultures independent of explant
1-2 g callus 10 ml liquid medium
Shaken 2 weeks
100 ml suspension cultures in 250 ml flasks (Erlenmeyer)
Subcultured by pipette or measured cylinder, e.g. 20 ml 'old' (source) suspension - 100 ml fresh medium/2 weeks
Filter
Freeze-dried
Vacuum
Extracted by solvent extract
Product may be in cells or media or both
Medium

Procedure for obtaining digoxin from cell suspension of *Digitalis lanata*

Uses of suspension culture

There are different uses of suspension culture:

a) It is possible to maintain cell suspension cultures in bioreactors. This cell suspension culture is used for producing different chemicals. These chemicals will be used in the production of drugs, cosmetics and agricultural chemicals. Thus it will not be necessary to farm plants for the purpose of acquiring the chemicals.

b) Cells suspension culture is also used to study physiological, biochemical and metabolic characteristics of plant cells.

c) It is also used to isolate certain special cells. These cells show tolerance to different stresses like salts, herbicides and drought conditions.

d) Cell suspension culture is very useful in inducing genetic variability in cells. This variability is produced through different physical and chemical mutagens.

5. Anther culturing

Following method is used in this technique:

(a) Mature anthers are cultured in a medium. This medium contains vitamins and growth regulators.

(b) The haploid tube cells within the pollen grains are divided. They produce **proembryos**. The proembryos consist 20 to 40 cells.

(c) Finally the pollen grains rupture and release the haploid embryos.

(d) A haploid plant can be produced experimentally from this haploid embryo.

(e) A chemical agent is added into haploid embryo. This chemical encourages chromosomal doubling. As a result diploid plants are produced. These plants are homozygous for all their alleles.

Anther culture is use to express recessive alleles in plants. Sometimes, recessive alleles govern desirable traits. Thus the plants express these traits.

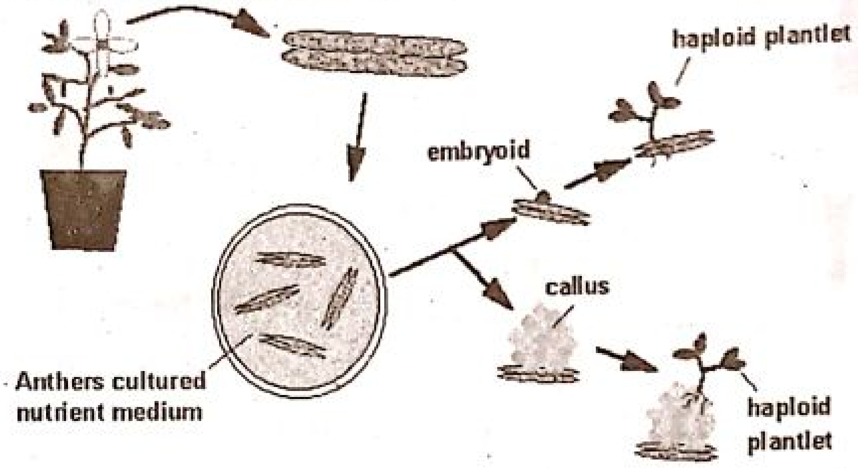
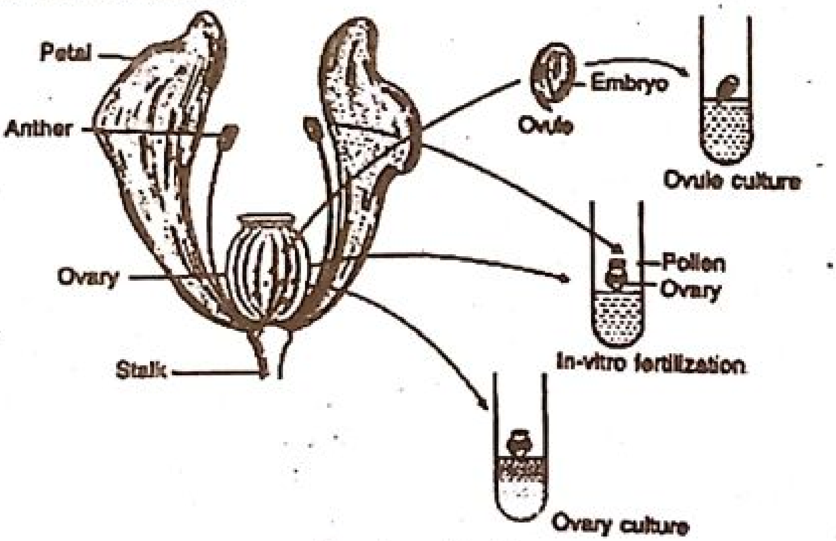


Fig: Anther culturing

5. Ovule culture techniques

It is an important technique in modern plant breeding. In this case, whole ovule is cultured. It is much easier to culture whole ovule than to isolate a single embryo. It is especially used in small seeded plants. This technique is used to for direct hybridization of various species like *Brassica*.



Ovule culturing

6. Embryo culture

There are following steps of this technique:

a) Embryos are isolated from young seeds. They are placed on a solid medium containing nutrients and vitamins.

b) The embryos are cultured at 25 °C. They are put first in darkness. They are kept here till seedlings are about 2 cm long. Root formation started in it.

c) Then they are placed in light. The seedlings grow.

d) The seedling then finally is planted in soil.

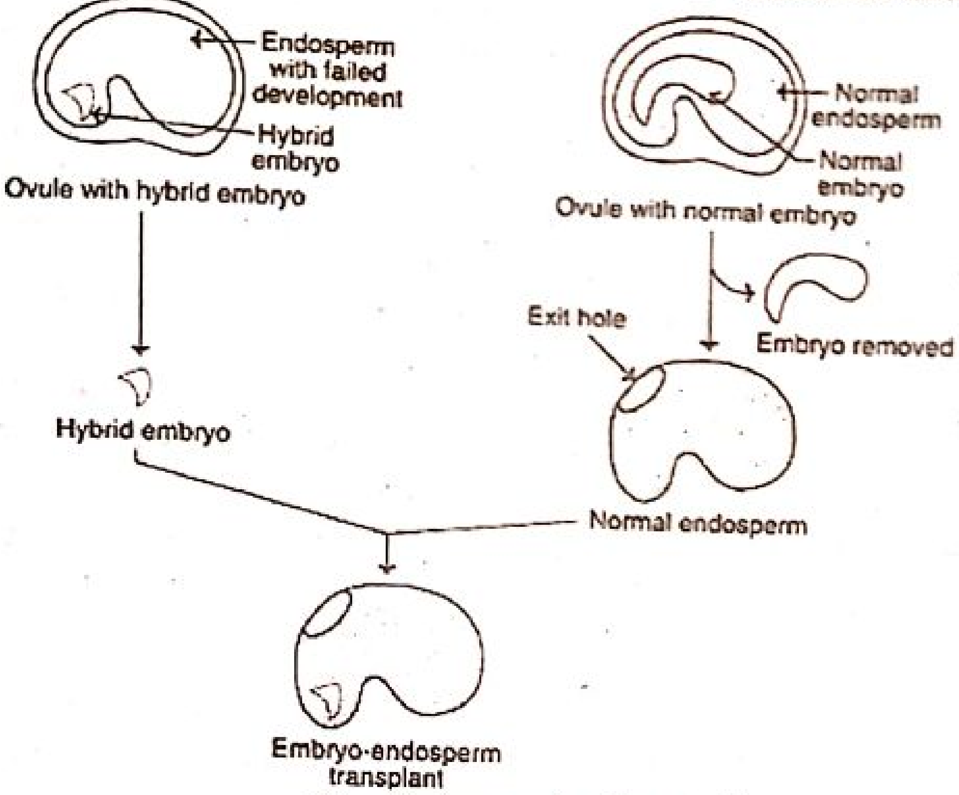


Fig: Embryo culturing

7. In vitro fertilization and pollination

Pollination and fertilization under in vitro condition is used for producing hybrid embryo. It is not possible by conventional method. In this technique, aseptic transfer of pollen grain on stigma is done under controlled condition. It produces hybrid embryos among plants.

This method gives viable seeds of hybrids. It is used to induce parthenogenesis and development of haploid embryos. It is used to study in detail the process of fertilization and embryogenesis in controlled conditions.

Application of tissue culture

1. It is used to reproduce plants which do not reproduce by normal methods.
2. It is used to express the recessive traits.
3. It is used to study the effect of different hormones on plant.
4. It gives virus free plants.
5. It is method of rapid propagation of plants.
6. It gives monoclonal and soma clonal plants.
7. Suspension culture is used to produce different types of drugs and alkaloid.

Uses or significance of tissue culture technique

1. **Commercial production of plants:** It is used for commercial production of plants. These plants are used as potting, landscape, and florist subjects. Here meristem and shoot culture is done. It produces large numbers of identical individuals.
2. **Conserving endangered species of plants:** It is used to conserve rare or endangered plant species.

3. **Screening of cells:** A plant breeder use tissue culture to screen cells. He does not need to screen whole plants. He screens cells for advantageous character like herbicide resistance/tolerance.
4. **Obtaining biopharmaceuticals:** It is used for large-scale growth of plant cells in liquid culture in bioreactors. These bioreactors are used for production of valuable compounds. These compounds are like plant-derived metabolites and recombinant proteins. These are used as biopharmaceuticals.
5. **Crossing of distantly related species:** It is used to cross distantly related species by protoplast fusion. It is also used for regeneration of the new hybrid.
6. **Study of different process:** It is used to rapidly study molecular basis for physiological, biochemical, and reproductive mechanisms in plants. Its example is in vitro selection for stress tolerant plants.
7. **Tissue culturing the embryo:** It is used to cross-pollinate distantly related species. Then tissue culture the resulting embryo. Such embryo otherwise normally die
8. **Introducing polyploidy:** It is used for chromosome doubling and induction of polyploidy. Its examples are doubled haploids, tetraploids, and other forms of polyploids. Antimitotic Agents like colchicine or oryzalin are used in it.
9. **Tissues for transformation:** It is used to form tissue for transformation. These are used for short-term testing of genetic constructs or regeneration of transgenic plants.
10. **Producing virus free plants:** Certain techniques like meristem tip culture can be used to produce clean plant material from virus affected stock. Potatoes and many species of soft fruit can be made virus free by this technique.
11. **Production of sterile hybrids:** It is used for production of identical sterile hybrid species.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Growth	The quantitative increase in plant body is called growth.
Meristem	Meristems are young tissues or group of cells that retain the potential to divide.
Apical Meristems	The meristems present at the tips of roots and shoot are called apical meristems.
Intercalary Meristems	The meristem situated at the bases of internodes is called intercalary meristem.
Lateral Meristems	The cylinders of dividing cells present in the vascular and cork tissue of the plants are called lateral meristems.
Primary Growth	In this growth, primary tissues are added by the apical meristem. It increases the length of the plant.
Secondary Growth	In this growth, secondary tissues are added by the intercalary or vascular cambium. It increases the thickness of plant.

Plant hormone	The special substances produced by the plants which influence the growth and plant responses are called plant hormones.
Apical dominance	The phenomenon in which shoot apex inhibits the growth of lateral buds is called apical dominance.
Abscission	The falling of leaves, flowers and fruits is called abscission.
Tropism	The bending of plant organs like coleoptile, stem and root toward or away from stimulus due to unequal growth is called tropism.
Seed dormancy	The physiological inability of a seed to grow is called seed dormancy.
Rosette dwarf	The plants with very short stem and crowed leaves are called rosette plant.
Bolting	The rapid stem elongation of rosette plant is called bolting.
Fruit setting	The start of fruit growth after pollination is called fruit setting.
Morphogenesis	The differentiation of different tissues like root, shoot from callous is called morphogenesis.
Leaf senescence	The degradative changes which lead to death of an organ or organism are called leaf senescence.
Tissue culture	The in vitro cultivation of any part of plant in nutrient medium is called tissue culture.
Callus	An undifferentiated group of cells is called callus.

MODEL SUBJECTIVE QUESTIONS

1. **What is growth? Discuss its different aspects.**
2. **What is meristem? Gives its types.**
3. **Give roles of Auxins in plant growth.**
4. **Give role of gibberellins in growth.**
5. **Give role of cytokinins in growth.**
6. **Give role of abscisic acid in growth.**
7. **Give role ethene in growth.**
8. **Describe different tissue culture techniques.**

SHORT QUESTIONS

1. **What is meant by open growth?**

Ans: The plants have a growth pattern called **open growth**. The plant adds new organs such as branches, leaves and roots throughout the life. Plant enlarges its body from the tips of roots and shoots.

2. **What is Apical Meristems? What its role in plant?**

Ans: **The meristems present at the tips of roots and shoot are called apical meristems.** They are primarily concerned with the extension of plant body. The perpetual growth zones are present at the apices of roots and stems. They increase the number of cells at the tips of roots and stem. Thus they play important role in primary growth.

3. **What is Intercalary Meristems? What its role in plant growth?**

Ans: **The meristem situated at the bases of internodes is called intercalary meristem.** These are the parts of apical meristem. They get separated from apex meristem by permanent tissues. They play important role in the production of leaves and flower. These are of temporary nature.

4. **What is Lateral Meristems?**

Ans: The cylinders of dividing cells present in the vascular and cork tissue of the plants are called lateral meristems.

5. **Differentiate between determinate and indeterminate growth.**

Ans: **Determinate:** Their growth is determinate i.e. they grow to certain size and then stop. For example leaves, flowers and fruits

Indeterminate: Their growth is indeterminate i.e. they grow by meristems that continually replenish themselves during remaining youthful age. For example, vegetative root and stem.

6. **Differentiate between primary and secondary growth.**

Ans: **Primary Growth:** In this growth, primary tissues are added by the apical meristem. It increases the length of the plant.

Secondary Growth: In this growth, secondary tissues are added by the intercalary or vascular cambium. It increases the thickness of plant.

7. **What are plant hormones? Name them.**

Ans: **The special substances produced by the plants which influence the growth and plant responses are called plant hormones.** Plant hormones are auxin, gibberellins, cytokinins, abscisic acid and ethene.

8. **Name some synthetic auxins.**

Ans: Indole butyric acid (IBA), Naphthalene acetic acid (NAA), 2,4-dichlorophenoxyacetic acid (2,4-D), Para chlorophenoxy acetic acid.

9. **What is the role of auxins in apical dominance?**

Ans: The terminal bud produces auxins. It inhibits the growth of lateral bud. Therefore, the main stem continues to grow. If the tip is cut off, the influence of the apex on the lateral buds is lost. Now lateral buds emerge and form branches.

10. **What is role of auxins in sex expression?**

Ans: Auxins change the sex ratio in some plants. The flowers of some plants like cucumber and ridge gourd are unisexual. But both male and female flowers are borne on the same plant (Monoecious). These plants produce a large number of male flowers. But it produces only a few female flowers.

11. **What is parthenocarpy? What is role of auxins in it?**

Ans: The phenomenon in which ovary changes into fruit without fertilization is called parthenocarpy. The production of auxin increases in ovary after pollination.

12. **What is abscission? What is role of auxins in it?**

Ans: **The falling of leaves, flowers and fruits is called abscission.** The green lamina of young leaves produce auxin. This auxin prevents the abscission of leaves. The old leaves cannot produce sufficient auxin. So they fall. If auxin is applied on such leaves, abscission is prevented.

13. **What is role of auxins in phototropism?**

Ans: A stem is exposed to light from one side. One half of the stern receives the light. The other half is shaded. Auxin produced at the tip. It is transported downward. The lighted half of the stem gets about 35% of auxin. But the shaded side receives about 65 % of auxin. As a result, the shaded half of the stem grows more than the lighted half. It bends the stem towards light.

14. What is seed dormancy? How it can be broken?

Ans: **The physiological inability of a seed to grow is called seed dormancy.** Dormant seeds do not germinate even under favourable conditions of water, air and normal temperature. Gibberellic acid breaks the dormancy in some seeds.

15. What are Rosette long day plants? Give role of gibberellins in it.

Ans: Rosette plants like Hyoscyamus and Samolus remain vegetative under short days. But they produce flowers in long days. The application of gibberellin makes the plants to flower even under short days.

16. What is differentiation? Give role of hormones in it.

Ans: **Differentiation of different tissues like root, shoot from callous is called morphogenesis.** The ratio of cytokinins to auxin controls the morphogenesis.

17. How does ABA inhibit growth?

Ans: ABA is growth inhibitor hormone. It inhibits the growth of root, stem, leaf and coleoptile. Even its very low concentration is effective. Gibberellin reverses the effect of ABA. Thus plant resumes normal growth. Therefore, abscisic acid and gibberellic acid have opposite effects on plants.

18. How does ethylene play role in fruit ripening?

Ans: **Ripening of fruits:** It is the most important effect of ethylene. The banana and apple are kept in storage for ripening. The rate of respiration of the fruit increases. It is called **climacteric respiration.** Such fruits are called **climacteric fruits**.

20. Give three applications of tissue culture.

Ans: It is used to reproduce plants which do not reproduce by normal methods. It is used to express the recessive traits. It is used to study the effect of different hormones on plant.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. The hormone which promote apical dominance is:

(a) Gibberellins (b) Auxins (c) ethene (d) Cytokinins

2. Abscission is prevented by:

(a) Gibberellins (b) Auxins (c) ethene (d) Cytokinins

3. Gibberellins was first obtained from:

(a) Plants (b) Algae (c) Fungi (b) Bacteria

4. Seed of dormancy can be broken by:

(a) Gibberellins (b) Auxins (c) ethene (d) Cytokinins

5. Leaf senescence is delayed by:

(a) Gibberellins (b) Auxins (c) ethene (d) Cytokinins

Answers: 1. (b) 2. (b) 3. (c) 4. (a) 5. (d)

Fill in blanks

1. The meristems present at the tips of roots and shoot are called __________ meristems.
2. The meristem situated at the bases of __________ is called intercalary meristem.
3. The cylinders of dividing cells present in the vascular and ________ tissue of the plants are

called lateral meristems.

4. Special substances produced by plants which influence growth and plant responses are called plant ________.
5. The phenomenon in which ovary changes into fruit without fertilization is called ________.
6. The production of __________ increases in ovary after pollination.
7. The rapid stem elongation of rosette plant is called ______.
8. The rate of respiration of the fruit increases. It is called ________ respiration.
9. _______are a class of plant hormones which promote cell division, or cytokinesis
10. This substance can cause cell division in tobacco pith cells. It was named _______.
11. The lump of undifferentiated cells is known as _______.
12. Application of _______to dicot seedlings causes drooping down of the leaves.
13. The rate of respiration of the fruit increases. It is called _______respiration.
14. The commercial compound _______breaks down and releases ethylene in plants.
15. All the _______plants have the same traits.
16. Somatic embryos are covered in a protective hydrated gel. It is called _______seeds.
17. The hormones which stimulate and promote growth in plants are called growth _______.
18. Hormones which inhibit growth and antagonize growth stimulators are growth _______.
19. Gibberellin was discovered by _______in 1928.
20. Gibberellic acid was the first _______to be discovered.

Ans 1. Apical 2. Internodes 3. Cork 4. Hormones 5. parthenocarpy 6. auxin 7. Bolting 8. Climacteric, 9. Cytokinin, 10. Kinetin, 11. Callus, 12. ethylene, 13. climacteric , 14. ethephon, 15. clonal , 16. Artificial, 17. Stimutators18. Inhibitors, 19. Kurosawa 20. gibberellin

Ture/False

1. The quantitative increase in plant body is called development.
2. The growth is limited to certain regions known as growing points.
3. The zone of elongation is present a little distance from apex of root and shoot.
4. The term phytohormone was used by Went in 1948
5. The hormones which stimulate and promote growth in plants are called growth stimutators.
6. Hormones which inhibit growth and antagonize growth stimulators are growth inhibitors.
7. Auxins and their role in plant growth were first described by Thimann .
8. Phenomenon in which shoot apex inhibits growth of lateral buds is called apical dominance.
9. Gibberellin was discovered by Kurosawa in 1928.
10. Gibberellic acid was the third gibberellin to be discovered.
11. The physiological inability of a seed to grow is called seed dormancy.
12. The rapid stem elongation of rosette plant is called elongation.
13. The start of fruit growth after pollination is called fruit setting.
14. Cytokinins (CK) are a class of plant hormones which promote cell division, or cytokinesis
15. This substance can cause cell division in tobacco pith cells. It was named zetin.
16. The lump of undifferentiated cells is known as callus.
17. The rate of respiration of the fruit increases. It is called climacteric respiration.
18. The commercial compound ethephon breaks down and releases auxin in plants.
19. Somatic embryos are covered in a protective hydrated gel. It is called artificial seeds.

Answers: 1. F. Growth, 2. T, 3. T, 4. F. Thimann, 5. T. 6, T. 7, F. Went, 8, T, 9. T, 10. First, 11. T, 12. F. bolting 13. T, 14. T, 15. F kinetin, 16. T, 17. T, 18. F. ethylene 19. T

Chapter 9

PHOTOPERIODISM

Syllabus

1. Definition, historical background
2. Short day, long day and day neutral plants
3. Role of phytochromes and hormones in photoperiodism

PHOTOPERIODISM

The response of plant to the relative length of light and dark period is called photoperiodism. There are number of plants responses controlled by photoperiods. Some of these are:

1. Flowering in short day and long day plants
2. Formation of tubers in potato and bulbs in onion is also promoted by short days.
3. Short days promote enlargement of tap root and storage of food in radish and carrot.
4. There is shedding of leaves. The growth of plant stop and it becomes dormant during the winter.
5. Photoperiod determines the ratio of male and female flower in some plants like hemp and maize.

HISTORICAL BACKGROUND OF PHOTOPERIODISM

Following plant physiologist played their role in the discovery of photoperiodism:

1. Julien Tournois

He performed experiments on hemp (*Cannabis sativus*) flower. He planted it early in the spring. It produces flowers. It remained in a vegetative stage when he planted it in later spring or summer. He concluded that flowering in hemp is controlled by duration of light. Tournois found that short photoperiods of 6 hours durations is required for flowering in hemp. It remained in a vegetative phase if this duration is more than 6 hours.

2. George Kleb (1918)

He was working with **house leek plants**. It is a long day plant. He found that the normal time of flowering for this plant is June. He induced flowering in it in midwinter in a greenhouse by artificial light. It was believed at that time that the role of light in the life of plants is nutritional. Light produce more carbohydrates. It causes flowering in it. George exposed hop and hemp to low light intensities of light for longer periods. The plants did not flower. It confirmed that photosynthesis did not play any role. Therefore, the photoperiod (day length) is more important than intensity of light.

3. Garner and Allard

They give first hypothesis about photoperiodism in 1920. They worked on two plants:

(a) Biloxi soybean

They germinated these plants in May, June, and August. They all flower in September and October. They observed that there are variations of 59 days in germination date from May and June. But there was difference of only 11 days for flowering in these plants. They suggested that there is seasonal timing mechanism for flowering in soybean.

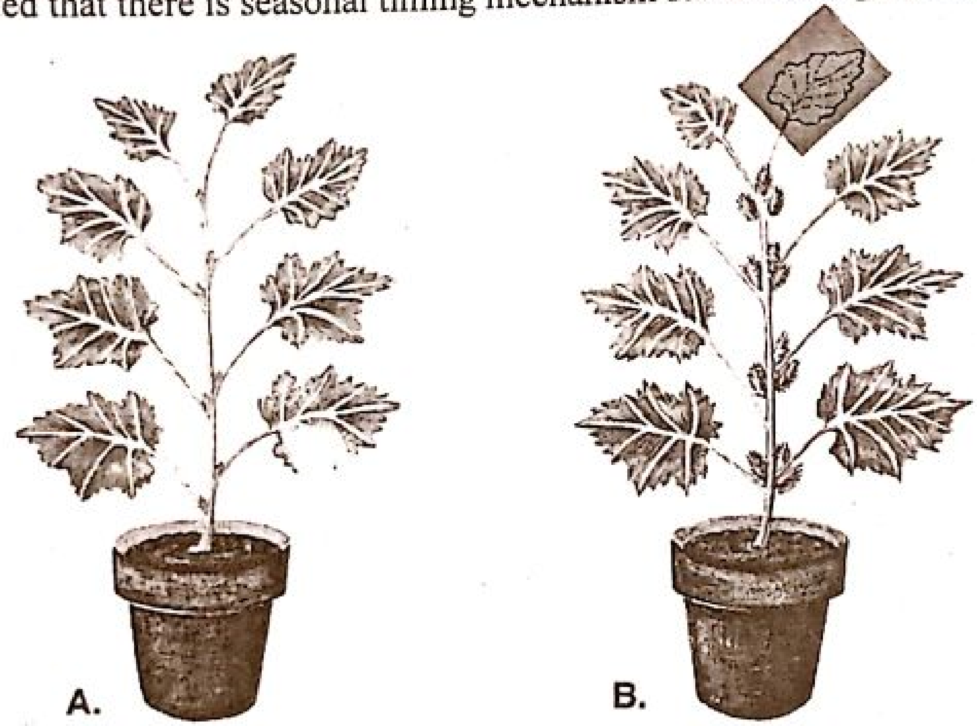


Fig: Experiment of day leng [illegible] A –no flowering) (B –flowering)

(b) Tobacco (Nicotiana tobaccum)

They also studied the flowering in tobacco [illegible] in Maryland state of U. S. A. They germinated seeds of tobacco plant during Feb Marc [illegible] in beds. They transplanted them in fields during April-May. The day length is 14 hours at that time. The plants flower during late summer. At that time, the day length was about 12 hours. Garner and Allard observed a mutant strain in the fields. It was taller. It had much larger leaves. It did not flower throughout the season. They named it **Maryland Mammoth**. They transferred it into green house at the end of the season. The plant flowered in winter and produced seeds. The days are shorter in winter.

Next Gamer and Allard grew plants during summer. They exposed them to day length equal to winter day (shorter duration of light). Then they placed the plants in dark chamber. They found that plant remains vegetative when the light period was increased during winter. Garner and Allard concluded that the length of light and dark periods within a 24- hour cycle promotes flowering. Garner and Allard called Maryland Mammoth a short-day plant (SDP). They also studied many other short day plants.

CLASSIFICATION OF FLOWERING RESPONSES

(a) Short Day Plants (SDP)

The plants that flower when day length is less than a certain critical length are called short day plants. These plants require specific short duration of light. They are actually long night plant. They need darkness more than a critical length. They can flower in 24 hours darkness. For example, xanthium flower under photoperiod less than 15 ½. The duration of light should be less than this critical time. Other examples of short day plants are Biloxi soybean, Cocklebur, Xanthium, Tobacco and Strawberry.

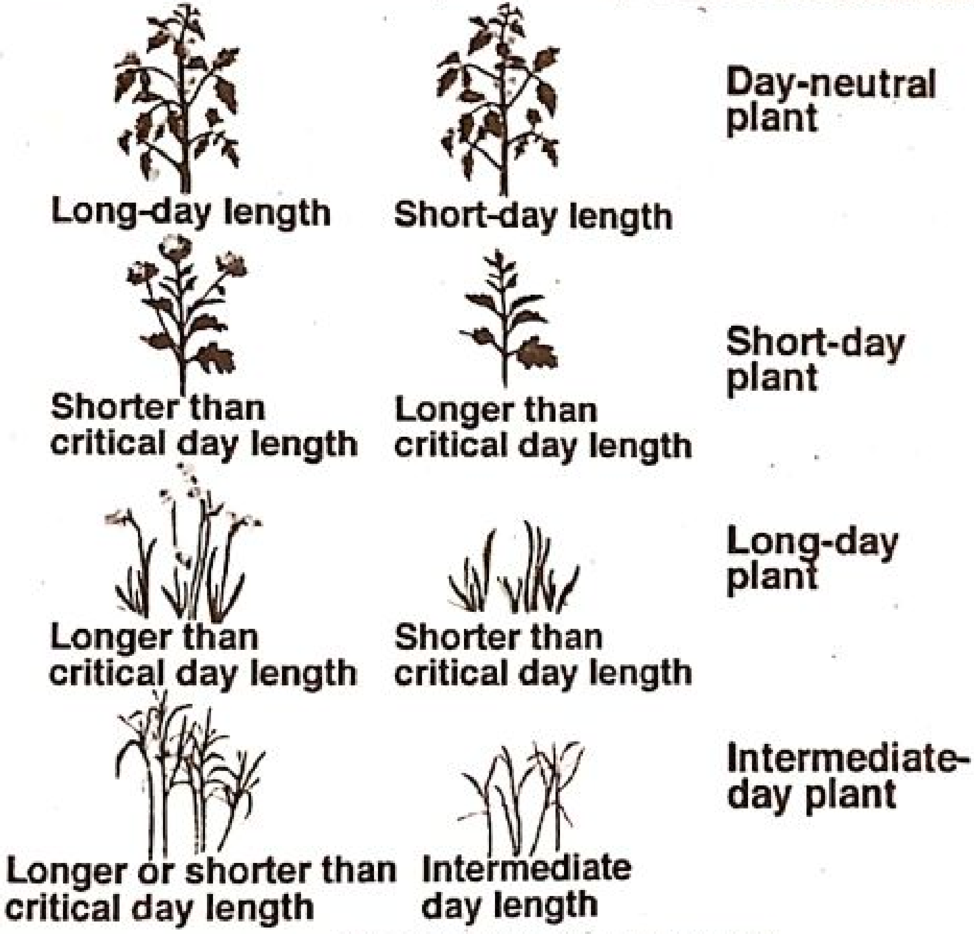

Day-neutral plant
Long-day length
Short-day length
Short-day plant
Shorter than critical day length
Longer than critical day length
Long-day plant
Longer than critical day length
Shorter than critical day length
Intermediate-day plant
Longer or shorter than critical day length
Intermediate day length

Fig: Day length responses

(b) Long Day Plants

The plants that flower when day length is more than a certain critical length are called long day plants. Dark period is not important for them. It means they can flower even they are exposed to 24 light. For example, the critical photoperiod of Hyoscyamus is more than 10 ½ hours. Other examples of long day plants are cabbage, spring wheat and spring barely.

(c) Long-short-day plants (LSDPs):

The plants which flower only after a sequence of long days followed by short days are called long-short-day plants. Examples of LSDPs are Bryophyllum, Kalanchoe, and Cestrum noctur-num (night-blooming jasmine). Such plants flower in the late summer and fall. The days are shortening in these days.

(d) Short-long-day plants (SLDPs)

The plants which flower only after a sequence of short days followed by long days are called short-long-day plants. Examples of SLDPs are Trifolium repens (white clover), Campanula medium (Canterbury bells), and Echeveria harmsii (echeveria). They flower in the early spring. They flower in response to lengthening days.

(e) Day Neutral Plants

These are also known as day length indifferent plants. Such plants flower under any photoperiod. Its examples are tomato, cucumber, cotton, maize and garden pea.

CRITICAL PHOTOPERIOD

The limit of the photoperiod up to which the short day plants flower is called critical photoperiod of short day plants. The limit above which long day plant flowers is called critical photoperiod of long day plants. The critical photoperiod varies from species to species. Both Xanthium and Hyoscyamus flower when they are exposed to 12 hours photoperiod.

a) Xanthium is a short day plant. Its critical photoperiod is less than 15 ½ hours. Therefore, 12 hour photoperiod acts as a short day for xanthium. It is less than its critical photoperiod.

b) Hyoscyamus is a long day plant. The critical photoperiod of. Hyoscyamus is more than 10 ½ hours. The photoperiod of 12 hours acts as a long day for Hyoscyamus. It is more than the critical photoperiod.

Therefore, it is clear that the same photoperiod can be short day for one species but long day for the other. Hence no absolute duration of light can be fixed for a short day and a long day. However, for convenience 6 - 8 of light is a critical photoperiod for the short day plants. The critical photoperiod of the all known short day plants is more than this. Similarly, 18-20 hours is a critical photoperiod for the long day plant. The critical photoperiod of all known long day plants is less than this limit.

Photoinductive cycle

The number of 24 hours cycles required to induce floral primordial in plant is called photoinductive cycle. The photoperiod may be:

(a) **Inductive photoperiod:** If a photoperiod causes flowering in a plant, it is called **inductive** photoperiod. Minimum duration of light needed to initiate floral primordia is called inductive photoperiod. Such plants are called photoperiodically induced. For example, we have short-day plant. We grow it under long-day conditions. Then it is temporarily transferred to short day conditions. Then again it is returned to long day environment again. Now flowering will initiate in it. It is photoperiodic induction.

Different numbers of cycles are required to induce flowering. It differs widely in different species. For example:

- Cocklebur is a short-day plant. It requires only one photoinductive cycle to flower.
- *Plantago* is a long day plant. It needs to 25 photoinductive cycles for flowering.

A plant receives minimum number of photoinductive cycles. Then it will flower.

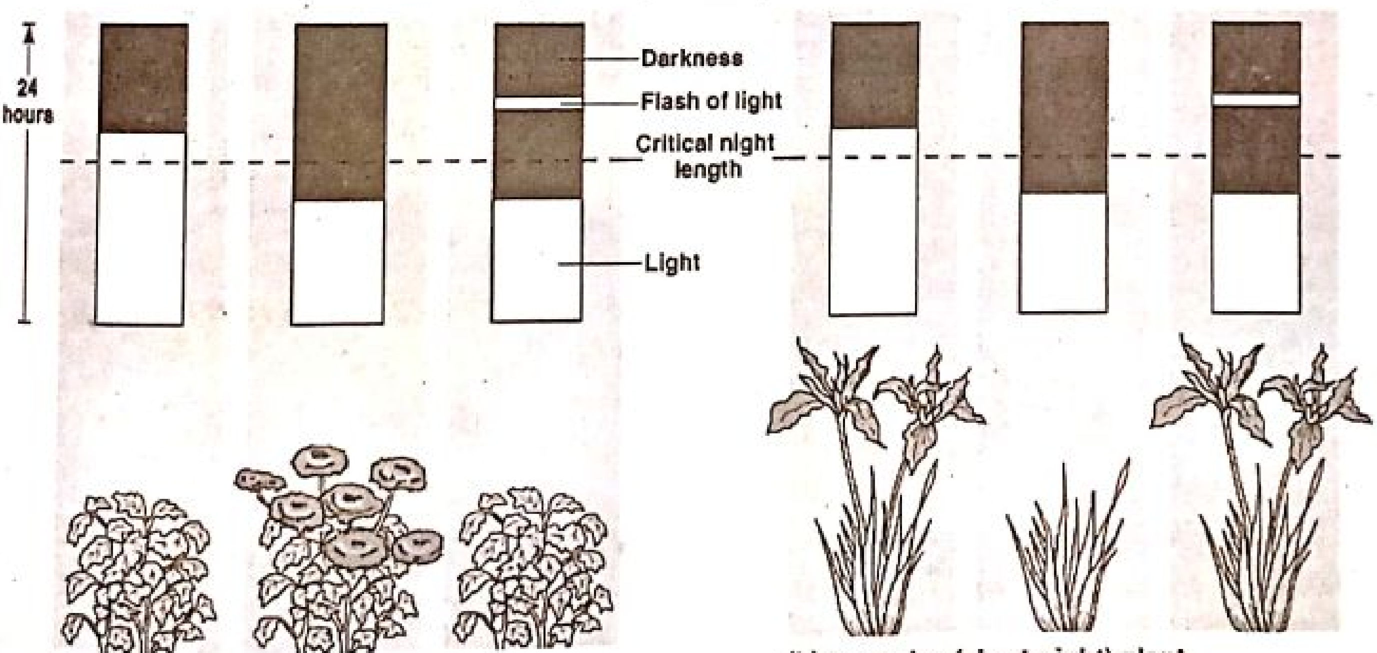
Returning it to non-inductive cycles does not stop flowering.

(b) **Non-inductive photoperiod:** If a photoperiod does not cause flowering in a plant, it is **non-inductive.** The effect of non-inductive cycle is different in short day and long day plant.

- In long-day plants non-inductive cycle does not modify the effects of a previous inductive cycle.
- In short-day plants, non-inductive cycle is inhibitory. It inhibits the effect of previous inductive cycle.

Importance of photoinductive period

Inductive and non-inductive photoperiods have different applications in long day and short periods. Short days are inductive for xanthium. But long days are non-inductive for xanthium. Similarly, long days are inductive for Hyoscyamus. But short day are non-inductive for it. Photoinductive cycle shows that some factor control flowering. This factor is accumulated during the inductive cycle. For example, enough factor is accumulated in Xanthium after only one cycle. It promotes flowering in it.



(a) Short-day (long-night) plant

(b) Long-day (short-night) plant

Role of dark period in photoperiodism

Further studies showed that the length of the dark period is critical for flowering. Thus the concept of photoperiod was changed:

1. Thus short-day plants are really long-night plants. If they are grown in short days and the long night is interrupted by a short light period, they will not produce flowers.
2. Long-day plants are short-night plants. If they are grown in short days and the long night period is interrupted by short light period, they will produce flower.

Role of Quality of light

Further experiments were performed. It revealed that flowering is also influenced by the quality of light. Cocklebur is a short day and long night plant. It will not flower if its long night is interrupted. Later it was found that **red light** was effective in preventing flowering. But **far-red** light reversed the effect of red light. The last light treatment always determines the response.

PHYTOCHROMES

The proteins present in the leaves which absorb light of different wave lengths are called phytochromes.

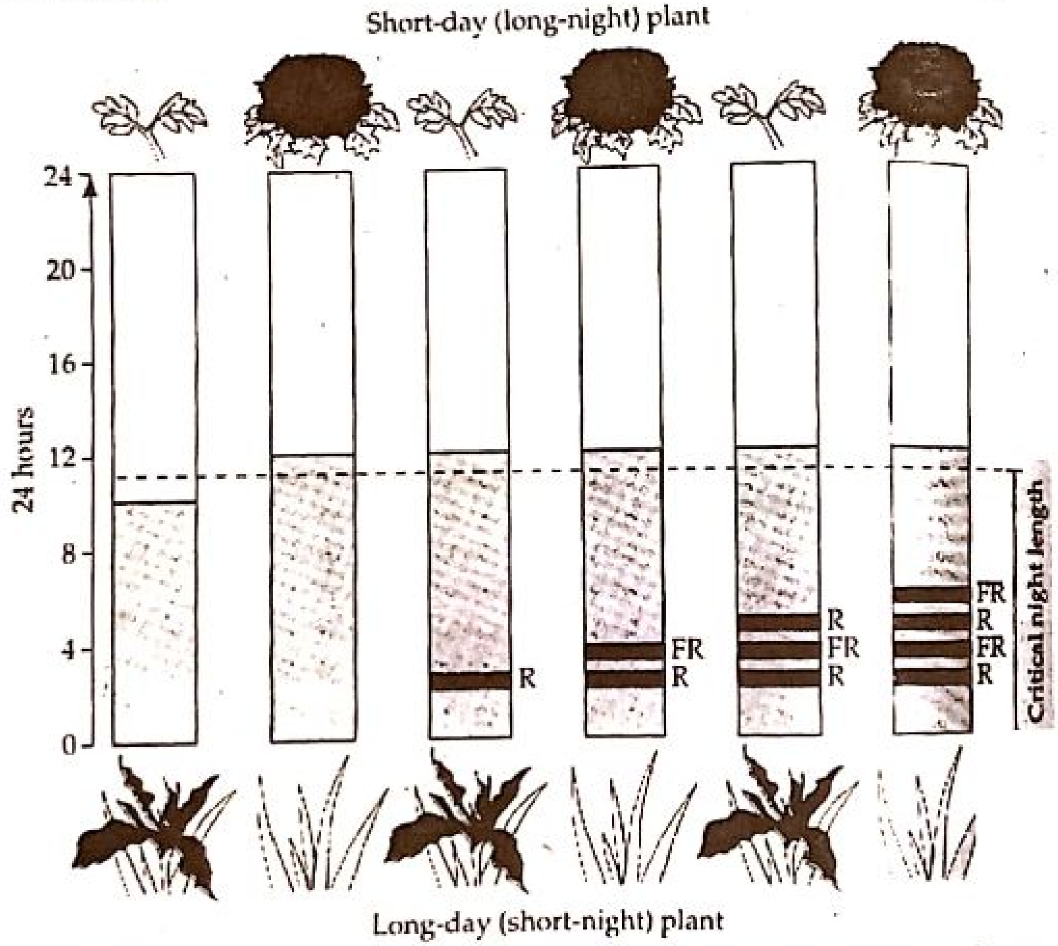


Fig: Effect of red and far red light in short and long day plants

DISCOVERY OF PHYTOCHROMES

White light consists of radiations from 390 to 810μ. The plant physiologist tried to search out the wave length most effective for flowering. There are following observations:

1. Xanthium plants are grown under long days. They then are exposed to short days. The dark period of the short day is interrupted in the middle by light of various wavelengths. It is found that the red light (660 mu) is the most effective in preventing flowering in short day plants.
2. However, if the dark period is interrupted by far-red light (730 mu) flowering is not affected. The plant continues to flower.
3. The red light is given in the middle of the dark period. It is immediately followed by a flash of far red. Then the plant flowers.
4. The far-red light is again followed by red. Once again the plant fails to flower.
5. The alternating sequence of exposure to red and far-red can be continued a number of times. Every time the effect of red is reversed by far-red and the effect of far-red is

reversed by red.

6. The last installment of light has great importance. If the last installment is far red the plant flowers. If the last installment is red, then the plant fails to flower.

Thus it is found that the red and far-red radiations are effective for flowering. These radiations must be absorbed by the plant. These are absorbed by certain pigments. Plants contain chlorophyll, carotenoids and anthocyanin pigments. But they do not absorb red and far-red radiations. **Borthwick** and **Hendricks** in 1959 were working in the U S Department of Agriculture at Maryland. They discovered a new pigment. It was named as **phytochrome. Siegelman** and **Firir** in 1964 extracted and purified phytochrome from etiolated maize leaf.

Type of Phytochrome

There are two forms of phytochrome. These are Pr and Pfr. These two pigments differ in their absorption peak.

1. **Phytochrome red (Pr):** It absorbs maximum light in the red region of the spectrum. It has wavelength of 660µ Pr is the inactive form.
2. **Phytochrome far red (Pfr):** It has the absorption peak in the far-red region at 730 µ. Only Pfr phytochrome is physiologically active.

Interconversions of phytochromes

These two types of pigments are interconvertible. There are two methods of their interconversions:

1. **Photoconversion:** The Pr phytochrome absorbs red light. It is converted into Pfr. Similarly when Pfr absorbs far red it is converted to Pr form. This is known as **photoconversion**. Photoconversion is very rapid. It is completed within 1-4 minutes.
2. **Thermal conversion:** Pfr spontaneously converted into Pr in the dark. This method of conversion is very slow. It takes a few hours. It depends on temperature. Therefore, it is called thermal conversion. Pr form does not show thermal conversion.

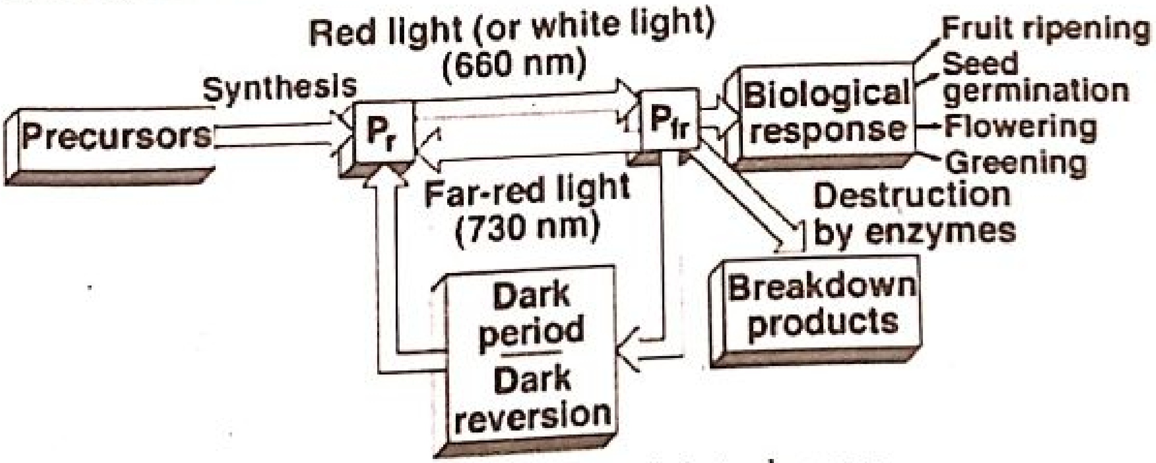


Fig: Interconversion of phytochromes

MECHANISM OF ACTION OF PHYTOCHROMES

MECHANISM OF PHOTOPERIODISM

There is following mechanism by which phytochrome controls the flowering in plants.

(a) Role of Phytochromes in Short Day Plants

The short day plants produce flowers in the presence of Pr. The phytochrome Pfr accumulates at the end of the light period in short day plants. The Pfr start a series of reactions. It finally inhibits flowering. There are two methods of conversion of Pfr to Pr:

a) Pfr undergoes thermal conversion in dark. The Pfr is slowly converted into Pr form when 8 ½ or more dark period is given. Now Pfr is disappeared. Its inhibition is also lost. Therefore, the plant flowers. Conversion of Pit Pr is not completed if dark period is less than 8 ½ hours. Hence the plant fails to flower.

b) Photoconversion is also possible. When the dark period is interrupted by a brief flash of red light in the middle, whatever Pr is produced is converted back to Pfr. Hence red light inhibits flowering. If red light is followed by far-red, Pfr is again converted into Pr. Therefore, the plant flowers.

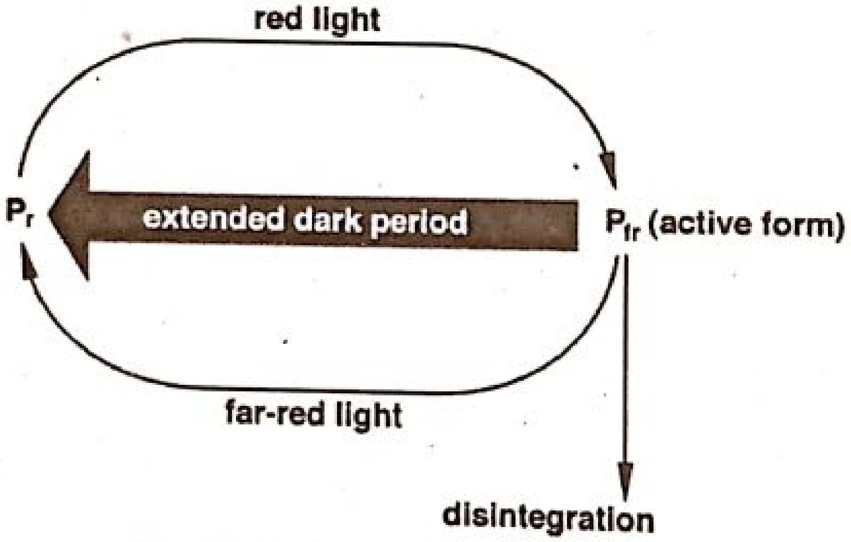


Fig: Phytochrome interconversions

(b) Role of Phytochrome in Long Day Plants

Long day plants produces flower in the presence of Pfr. Pfr also accumulates at the end of the light period in long day plants. Pfr start a series of reactions. It finally produces flower. Thus Pfr causes flowering in long day plants.

a) Thus Pfr should not be allowed to convert into Pr. Pr inhibits flowering in long day plants. Pfr can convert into Pr in dark. Therefore, plant should be given less darkness than critical time. Hyoscyamus plant is exposed to 10 ½ hours of light and 13 ½ hours of dark. Conversion of Pfr to Pr is not completed in the dark. Therefore, the plant flowers. If the dark period is more, then Pfr disappears. Therefore, flowering is inhibited.

b) If a flash of red light is given, Pr is converted into Pfr. Thus Pfr is restored. Hence red light causes flowering.

ROLE OF HORMONES IN PHOTOPERIODISM

ROLE OF FLORIGEN

The phytochromes are present in the leaf. But the flowers are produced at the stem tip and its branches. The apical or lateral buds express the stimulus of flowering. It was believed that some substance or stimulus moves from the leaf to the buds. This substance is a hormone. A Russian plant physiologist **Chailakhyan** named it **florigen**. Florigen is a hypothetical flowering hormone. It has following properties:

(a) Translocation of florigen

1. **Translocation with same plant:** This hormone is formed in the leaves. Then this hormone multiplies itself. It is the unique property of this hormone. Then it is translocated through the phloem to the apical and lateral buds. It causes flowering in them.
2. **Translocation between different plants of same specie:** Florigen can move from one plant to the other by graft union. It can be proved by a simple experiment. A number of xanthium seedlings grown under long days. The adjacent branches of a number of plants are grafted together in a series. Only the terminal branches are exposed to short days. It causes flowering of all the plants. Therefore, florigen moves from one plant to the other through the graft union. It can also move both in the upward and downward directions.
3. **Translocation between different plants of different species:** Two different taxonomically related plants can also be grafted together. Tobacco is a short day plant. Hyoscyamus is a long day plant. Both belong to the family Solanaceae. Now branch of tobacco is grafted to Hyoscyamus. They are kept under short day conditions. Tobacco starts flowering. Interestingly Hyoscyamus plants also start flowering. Thus florigen formed in tobacco is translocated to Hyoscyamus. It causes flowering in it. Similarly, when they were placed in long day condition again both produces flower. It indicates florigen is universal flower forming substance. It found in all the plats like LDP, SDP, DNP, SDLPF and LDSDP. Furthermore, florigen of monocots can cause flowering in dicot and vice-versa.

(a) Chemical nature of florigen

A number of attempts have been made to extract florigen hormone. **Hamner and others** (1964) extracted a substance from the inflorescence of Xanthium. But this substance was not effective in stimulating flowering of even Xanthium plants. There are five plant growth hormones: gibberellins, cytokinins, abscisic acid and ethylene. Some plant physiologist suggested that some of these hormones might be acting as florigen. Experiments were performed on these hormones.

1. Application of auxin causes flowering only in one of the short day plants pineapple.
2. Gibberellin causes flowering only in rosette long day plant like Hyoscyamus and vernalizable plant like carrot. GA causes flowering in only one short day plant.
3. Similarly, abscisic acid, cytokinin and ethylene also cause flowering in few species.
4. Chailakhyan suggested that two factors are involved in the flowering stimulus. First factor is **gibberellins** and the second factor is **anthesins**. Both gibberellin and anthesins collectively acts a florigen. But it cannot be proved experimentally.

Therefore, no one hormone is taken as florigen. It is possible that the flowering stimulus is transmitted by mixture of hormones.

Fig: Transfer of florigen from plant to the other

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Photoperiodism	The response of plant to the relative length of light and dark period is called photoperiodism.
Short Day Plants (SDP)	The plants that flower when day length is less than a certain critical length are called short day plants.
Long day plants	The plants that flower when day length is more than a certain critical length are called short day plants.
Inductive	If a photoperiod causes flowering in a plant, it is called inductive photoperiod.
Non-inductive	If it does not cause flowering, then it is non-inductive.
Phytochromes	The proteins present in the leaves which absorb light of different wave lengths are called phytochromes.
Phytochrome red (Pr)	It absorbs maximum light in the red region of the spectrum. It has wavelength of 660μ Pr is the inactive form.
Phytochrome far red (Pfr)	It has the absorption peak in the far-red region at 730 μ. Only Pfr phytochrome is physiologically active.

MODEL SUBJECTIVE QUESTIONS

1. **What is photoperiodism? Give its historical background.**
2. **Give classification of plants on the basis of photoperiodic responses.**
3. **What is critical period? Explain.**
4. **What are phytochromes? Give their mechanism of action.**
5. **Discuss role of hormones in photoperiodism.**

SHORT QUESTIONS

1. **What is photoperiodism?**

Ans: The response of plant to the relative length of light and dark period is called photoperiodism.

6. **Give three photoperiodic responses of plants.**

Ans: Flowering in short day and long day plants. Formation of tubers in potato and bulbs in onion is also promoted by short days. Short days promote enlargement of tap root and storage of food in radish and carrot.

3. **What are (a) Short Day Plants (SDP)? Give example.**

Ans: **The plants that flower when day length is less than a certain critical length are called short day plants.** Examples of short day plants are Biloxi soybean, Cocklebur, Xanthium, Tobacco and Strawberry.

4. **What are day neutral plants? Give example.**

Ans: These are also known as day length indifferent plants. Such plants flower under any photoperiod. Its examples are tomato, cucumber, and cotton, maize and garden pea.

5. **What are long day plants? Give example.**

Ans: **The plants that flower when day length is more than a certain critical length are called long day plants.** Its examples of long day plants are cabbage, spring wheat and spring barely.

6. **What is critical period for photoperiodic responses?**

Ans: The limit of the photoperiod up to which the short day plants flower is called critical photoperiod of short day plants. The limit above which long day plant flowers is called critical photoperiod of long day plants.

7. **Differentiate between inductive and non-inductive photoperiods.**

Ans: If a photoperiod causes flowering in a plant, it is called **inductive** photoperiod. If it does not cause flowering, then it is **non-inductive.**

8. **What are phytochromes?**

Ans: The proteins present in the leaves which absorb light of different wave lengths are called phytochromes.

9. **What is Photoconversion?**

Ans: The Pr phytochrome absorbs red light. It is converted into Pfr. Similarly when Pfr absorbs far red it is converted to Pr form. This is known as **photoconversion.**

10. **What is Thermal conversion?**

Ans: Pfr spontaneously converted into Pr in the dark. This method of conversion is very slow. It takes a few hours. It depends on temperature. Therefore, it is called thermal conversion. Pr form does not show thermal conversion.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. **Experiments on hemp were performed by:**

(a) Garner (b) Julien (c) Kleb (d) Hamner

2. **Experiment on house leek plants were performed by:**

(a) Garner (b) Julien (c) Kleb (d) Hamner

3. **Biloxi soybean flowers in:**

(a) January (b) June (c) October (d) December

4. **Maryland Mammoth is:**

(a) Soya bean (b) Wheat (c) Tobacco (d) rice

5. **Which of the followings is not short day plant?**

(a) Cotton (b) Cocklebur (c) Xanthium (d) Tobacco

6. **Which of the followings is day neutral plant?**

(a) Cotton (b) Cocklebur (c) Xanthium (d) Tobacco

7. **Which of the followings long day plant?**

(a) Cotton (b) tomato (c) Xanthium (d) cabbage

8. The critical time period for xanthium is less than hours:

(a) 12 (b) 14 (c) 16 (d) 15

9. The critical time period for Hyoscyamus is less than:

(a) 12 (b) 14 (c) 10 (d) 15

10. Borthwick and Hendricks discovered:

(a) Photoperiodism (d) Phytochrome (c) dormancy (d) None

10. Chailakhyan named:

(a) Photoperiodism (d) Phytochrome (c) dormancy (d) florigen

Answers 1. (b) 2. (c) 3. (c) 4. (c) 5. (a) 6. (a) 7. (d) 8. (d) 9. (c) 10. (d)

Fill in blanks

1. Response of plant to relative length of light and ________ period is called photoperiodism.
2. The photoperiod of 12 hours acts as a _______ day for Hyoscyamus.
3. Proteins present in the leaves which absorb light of different wave lengths are called ______.
4. Siegelman and ______ in 1964 extracted phytochrome from etiolated maize leaf.
5. The short day plants produce flowers in the presence of _____.
6. Long day plants produces flower in the presence of ____.
7. Chailakhyan suggested that two factors are involved in the flowering stimulus. First factor is ______ and the second factor is anthesins.
8. Garner and _______ give first hypothesis about photoperiodism in 1920.
9. Number of 24 hours cycles required to induce flower in plant is called _______ cycle.
10. If a photoperiod does not cause flowering in a plant, it is _______.
11. White light consists of radiations from 390 to _______μ
12. The Pr phytochrome absorbs red light. It is converted into _______.
13. A Russian plant physiologist _______named it florigen.
14. There are two forms of phytochrome. These are Pr and _______.
15. Tournois found that short photoperiods of _______ hours is required for flowering in hemp.
16. Pfr spontaneously converted into Pr in the _______.

Ans 1. Dark, 2. Long, 3. Phytochromes, 4. Firir, 5. Pr, 6. Pfr, 7. Gibberellins, 8. Allard 9. photoinductive, 10. non-inductive, 11. 810, 12. Pfr, 13. Chailakhyan, 14. Pfr, 15. 6. 16dark

True/False

1. Tournois found that short photoperiods of 10 hours is required for flowering in hemp.
2. Garner and Allard give first hypothesis about photoperiodism in 1920.
3. Xanthium is a short day plant. Its critical photoperiod is less than 15 ½ hours.
4. Number of 24 hours cycles required to induce flower in plant is called inductive cycle.
5. If a photoperiod does not cause flowering in a plant, it is non-inductive.
6. White light consists of radiations from 290 to 810μ
7. There are two forms of phytochrome. These are Pr and Pfr.
8. The Pr phytochrome absorbs far red light. It is converted into Pfr.
9. Pfr spontaneously converted into Pr in the dark.
10. The short day plants produce flowers in the presence of Pfr.
11. Long day plants produces flower in the presence of Pfr.
12. A Russian plant physiologist Chailakhyan named it florigen.

Ans: 1. F. 6, 2. T, 3. T, 4. F. photoinductive, 5. T, 6. F 390, 7. T, 8. T, 9. Red, 10. F. Pr
11. T, 12. T

Chapter 10

SEED DORMANCY

Syllabus

1. Definition and causes of seed dormancy
2. Methods of breaking seed dormancy

SEED DORMANCY

The physiological inability of a seed to germinate even under favourable condition is called seed dormancy. Many kinds of seeds can germinate immediately after maturation. The seeds in some species of citrus may germinate in the fruit. But in some cases seed passes a period of rest or inactivity before germination. Such seeds do not germinate even in favourable external conditions. Something blocks the processes germination. It is seed dormancy.

CAUSES OF SEED DORMANCY

There are following causes of seed dormancy:

1. Hard Seed Coat

Seed coats of most seeds are composed of several layers. These layers are derived from integuments of seeds. Some seeds have additional coat layers. These are derived from endosperm. The seed coat cells contain cellulose, hemicelluloses, lignin, proteins and waxes. These chemicals lose water during maturation of seeds. They form a hard protective layer around the embryo. Seeds of such species possess hard seed coat. Most of these seeds belong to the family, Leguminosae and Malvaceae. Such seeds remain dormant. Hard seed coat prevents germination due to following reasons:

(a) Hard seed coat prevents the entry of water into the seed. Such hard seed coat is common in members of Leguminosae.

(b) Hard coat obstruct exchange of gases, especially oxygen. Oxygen is necessary for respiration. Many seeds are permeable to water and dissolved gases like oxygen. But seed coats in some plants are permeable to oxygen and impermeable to carbon dioxide. Carbon dioxide produced inside the seeds during respiration. It inhibits seed germination and causes dormancy.

(c) In some seeds, strophiolar plug develops. It blocks micropyle. Therefore, the seeds are unable to absorb water and oxygen. Thus seeds remain dormant.

(d) Some seed absorb water and gases necessary for germination. But they have extremely hard seed coats. Hard seed coat causes mechanical resistance. So embryo cannot expand. Thus radicle does not come out. Therefore, seed remains dormant

2. Immature Embryo

The embryo is fully developed inside the seed in most of the plants before shedding from the parent plant. But development of the embryo is incomplete at dispersal in few cases like Fraxinus and Anemone. Such seeds remain dormant and fail to germinate. Such seeds imbibe water, and the development of the embryo is completed in a few weeks. Then the embryo is fully developed. Now the seed can germinate under favourable conditions.

In some cases, embryo is fully developed. It is provided with all conditions necessary for germination. But they do not grow. Examples of such plants are plants of family rosaceae like apple, pear etc. The embryos of these plants require some period of development. Changes occur during this period. These changes are called **afterripening**. It then breaks the dormancy.

3. Light Sensitive Seeds

There two type of seeds for light sensitivity:

(i) Positive photoblastic seeds: Seeds of most of the species germinate equally well both in the dark and in light. Therefore light is not necessary for germination. However, seeds of some species like lettuce remain dormant in the dark. They do not germinate till these are exposed to light. These are called **positive photoblastic seeds**. Therefore dark inhibits germination in these seeds.

(ii) Negative photoblastic seeds: Seeds of some species like *phlox*, *Nemophila* and *Silene* remain dormant when exposed to light. They germinate only in the dark. These are called negative photoblastic seeds.

4. Chilling Requirement

Seeds of many temperate trees remain dormant and do not germinate after harvest. Its examples are apple, walnut and inus. Such seeds need chilling temperature (1-5°C) for a few weeks. This requirement is met in nature. These seeds lie buried in the soil during winter. Therefore they get chilling temperature. But some seed become dormant in nature. They need artificial chilling.

5. Dormancy due to growth inhibitory chemicals

There are several naturally occurring compounds which inhibit germination of seeds. Seeds of many species contain several phenolic compounds. These phenolic compounds are **ferulic acid, parasorbic acid and coumarin**. These compounds are present in the embryo or in the seed coats. They inhibit the germination. Sometimes, an inhibitory hormone abscisic acid prevents germination.

METHODS OF BREAKING SEED DORMANCY

Following methods are used to break the seed dormancy:

1. Methods of breaking dormancy of hard seed coat

The dormancy of hard seed coat can be broken by following methods:

(a) Seed coat can be removed from such dormant seed. Thus they can germinate under favourable conditions. But removal of the entire seed coat is not possible. It can injure the embryo. Therefore the seed coat is punctured or mechanically ruptured by rubbing. This process is called **scarification**.

(b) The seed is treated with hot water or concentrated sulphuric acid for very short duration. It makes the seed coat soft and dormancy of seed is broken.

(c) In nature, seed remain buried in the soil. The action of soil micro-organisms makes its hard wall soft. Therefore, the dormancy of seed is broken.

2. Method of breaking dormancy of light sensitive seeds

The dormancy of light sensitive seeds can be broken by following methods:

(a) **Exposure to white light:** The exposure to light promotes this process. Its other examples are seeds of tobacco, tomato, Betula and Digitalis. Such seeds respond to a light only after imbibing 30—40% moisture. Light is ineffective in the dry condition.

(b) **Exposure to red and far red lights:** The exposure to very low intensity of light for short duration of 1—2 minutes is sufficient to overcome dormancy. **The red part of white light of wavelength of 660µ is very effective for germination.** If the seeds is exposed to far red radiation (730 µ) germination is inhibited. If the seed is first exposed to red light and immediately afterwards to far red, then again germination is inhibited. It means that the effect of red light is cancelled by far-red. The far-red is immediately followed by red light, now the seeds germinate. It means the effect of far-red is reversed by red light. The seed can be exposed to red and far red a number of times. The effect of red is cancelled by far red and vice versa. The behaviour of the seed depends upon the last radiation given. If the last installment given is red, then the seed germinates. If it is far red, then the seed fails to germinate.

(c) **Role of phytochromes:** Borthwick and Hendricks were working in the U.S. Department of Agriculture. They discovered new pigment in plants. This pigment was named **phytochrome**. Phytochrome is responsible for absorbing red and far-red radiations. They control several morphogenetic phenomena like seed germination and flowering.

(d) **Use of plant hormones:** The application of the hormones, gibberellic acid and kinetin can replace the red light requirement for germination of lettuce seeds. Therefore, seeds can germinate in the presence of these hormones in the total darkness.

(e) **Role of darkness:** The red far-red reversibility and phytochrome does not play any role in negative photoblastic seeds. Therefore, the dormancy of negative photoblastic seed can be broken by placing them in more than critical dark period.

3. Method of breaking dormancy of chilling requiring seeds

There are two methods to break the dormancy of chilling requiring seeds:

(a) **Stratification:** The dormancy of chilling required seed is broken by stratification. **Low temperature requirement given to the seeds to break their dormancy is called stratification.** Dry seeds cannot be stratified. A minimum amount of moisture is required. Therefore, such seeds are allowed to imbibe water. Then they are exposed to low temperature.

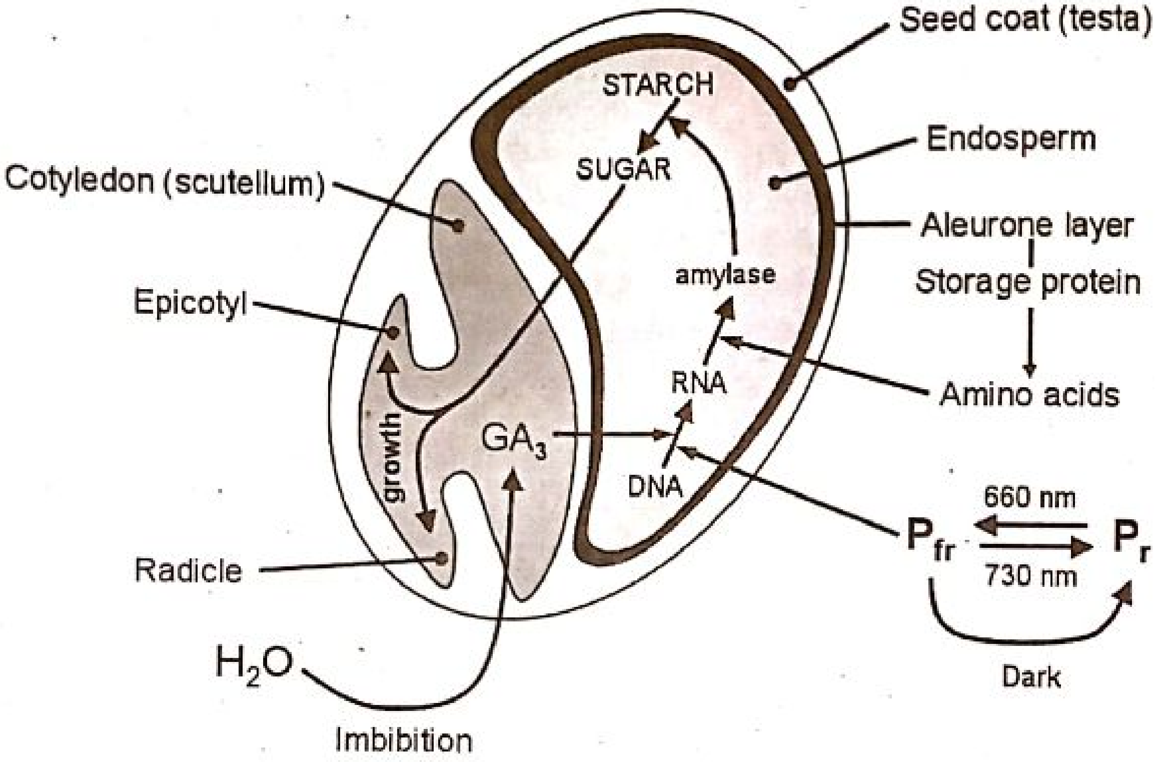


Fig: Breaking seed dormancy

(b) Chemical scarification: It is done in laboratory. Different chemicals are used to break dormancy:

- Alcohols or other fat solvents are used in it. These chemicals dissolve away waxy materials. Such materials block water entry.
- In some cases, concentrated acids may be used. The seeds of cotton and many tropical tree legumes are soaked in concentrated sulphuric acid. It softens the hard seed coats. Thus seeds become permeable to water and gases.
- Dipping the seeds in boiling water may also break seed dormancy.

(c) Use of hormone gibberellic acid: Such seeds contain an inhibitory hormone namely abscisic acid. This hormone disappears during stratification. Now gibberellic acid appears. It promotes growth in seed. Therefore, dormancy due to chilling requirement is under the control of promoter and inhibitor hormones. Thus the chilling requirement can be replaced by applying gibberellic acid. Therefore, such seeds can germinate in the presence of this hormone. They do not require chilling temperatures.

4. Impaction

In some seed, a cork-like plug is present in micropyle. It is called striphiolar plug. Water and oxygen are unable to penetrate in such seeds. In this case, vigorous shaking of the seeds dislodges this plug. Thus the seed start germination. The treatment is called **impaction**.

5. Use of growth promoting substances for breaking seed dormancy

Certain chemicals promote the seed growth. **Potassium nitrate, thiourea** and **ethylene chlorhydrin** are the most commonly used germination promoters. Similarly, the application of some of the plant hormones like gibberellic acid, cytokinin and ethylene also promotes seed germination.

DEFINITIONS AND KEY POINTS

TERMS	DEFINITIONS
Seed dormany	The physiological inability of a seed to germinate even under favourable condition is called seed dormancy.
Scarification	The seed coat is punctured or mechanically ruptured by rubbing. This process is called scarification.
Startification	Low temperature requirement given to the seeds to break their dormancy is called stratification

OBJECTIVES

Fill in the blanks:

1. Physiological inability of a seed to germinate is called seed _______.
2. The seeds in some species of _______ may germinate in the fruit.
3. Seed _______ of most seeds are composed of several layers.
4. Hard seed coat prevents the entry of _______ into the seed.
5. Seeds of some species like lettuce remain dormant in the _______.
6. Plants germinate only in the dark. These are called negative _______ seeds.
7. Sometimes, an inhibitory hormone _______ acid prevents germination.
8. Seed coat is punctured or mechanically ruptured by rubbing in _______.
9. The red part of white light of wavelength of _______μ is very effective for germination.
10. Red far-red reversibility/ phytochrome does not play any role in negative _______ seeds.
11. Low temperature requirement given to seeds to break dormancy is called _______.

Ans: **1. Dormancy, 2. Citrus, 3. Coats, 4. Water, 5. Dark, 6. Photoblastic, 7. abscisic, 8. scarification, 9. 660, 10. Photoblastic, 11. stratification**

True/False

1. Physiological inability of a seed to germinate is called seed dormancy.
2. The seeds in some species of citrus may germinate in the fruit.
3. Seed coats of most seeds are composed of sing layers.
4. Soft seed coat prevents the entry of water into the seed.
5. However, seeds of some species like lettuce remain dormant in the dark.
6. These seeds germinate only in the dark. These are called photoblastic seeds.
7. Sometimes, an inhibitory hormone abscisic acid prevents germination.
8. Seed coat is punctured or mechanically ruptured by rubbing in scarification.
9. The red part of white light of wavelength of 600μ is very effective for germination.
10. Low temperature requirement given to seeds to break dormancy is called stratification.

Ans: **1. T, 2. T, 3. F. several, 4. F.** Hard, 5. T, 6. F. negative, 7. T. 8. T, 9. F. 660, 10. T

Chapter 11

VERNALIZATION

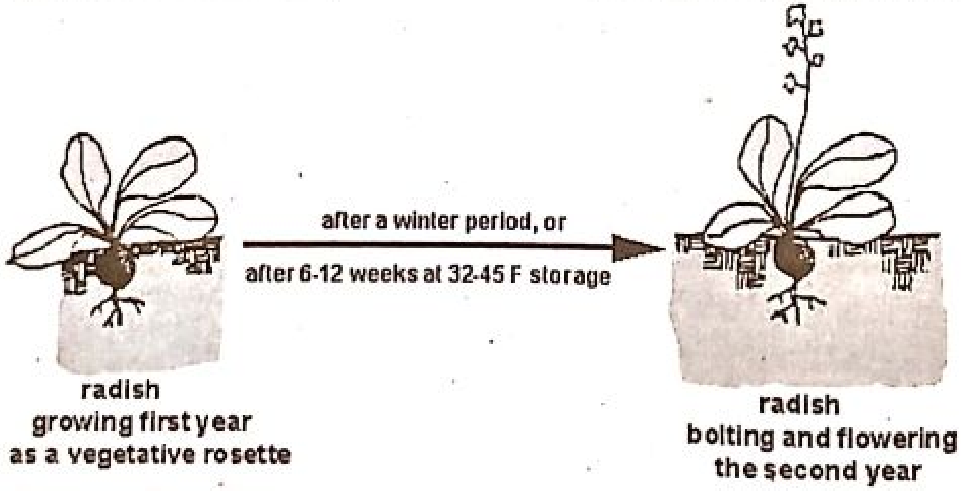
Syllabus
Vernalization: Annual and biennial forms
Hormonal concept and phasic development theory

VERNALIZATION

The low temperature treatment given to the seed or plant for stimulating flowering in them is called vernalization.

Some seeds required low temperature treatment to break dormancy. Similarly shoot bud dormancy in some plants like Acer and Betula is overcome by low temperature. But the low temperature requirement for processes other than flowering is not taken as vernalization.

Seed is given low temperature treatment during vernalization. Its effect persists and flowering takes place much later. Thus the effect of vernalization is inductive in nature. Therefore, the plant need not be exposed to low temperature at the time of flowering.



Discovery of vernalization

J. Gustav Gassner (1928) was a German plant physiologist. He was working with rye (*Secale cereale*) found that temperature is critical during early stages of seed germination. He showed flowering and fruiting depends on temperatures during this critical stage. There are two varieties of rye:

1. **Winter Petkus rye:** Winter Petkus rye is sown in the field in the fall of the year. It germinates and develops a few leaves. Then winter comes. So further growth is

checked for several months due to low winter temperatures. Some plants are even covered by snow. The temperature becomes moderate in the spring. Now the plants resume growth and produce a grain crop.

2. **Spring Petkus rye:** The spring Petkus rye is sown in the spring. It germinates immediately and its vegetative and reproductive growth occurred. It is harvested in winter.

Experiment of Gassner

He planted winter rye in spring. The seeds germinate and produce vegetative plants. But they did not flower until late in the growing season. The winter variety requires low temperature. Gassner found that winter Petkus rye could be given low temperature requirement artificially. He placed imbibed seeds in chilling temperatures between 2 to 5 °C for 5 to 6 weeks. He planted the chilled seeds in the spring. They grew and flowered like ordinary Petkus rye. Thus he discovered the phenomenon of vernalization.

Vernalization in Annual and Biennial Forms (Qualitative and Quantitative Vernalization)

There are two types of plants:

1. Annual forms (Quantitative vernalization)

The plants which survive one growing season are called annual plants. Its examples are rye, pea and gram. They are quantitative in nature. These plants can flower without vernalization. But vernalization develops the flowering earlier in these plants. For example Petkus rye flowers in 15 weeks without vernalization. But it takes only 7 weeks when it is given low temperature treatment.

2. Biennial forms (Qualitative vernalization)

The plants which survive two growing seasons are called biennial plants. Its example is Hyoscyamus. It has qualitative vernalization requirement. Their first growing season is before winter. They are sown in summer. They develop vegetative body in first growing season. They store food in their roots. Then winter comes. Vegetative plant dies. After winter the underground root give rise to new plant body. It is their second growing season. The plant develops flowers and seeds. It is harvested in spring. These plants fail to flower without vernalization. They remain vegetative indefinitely without vernalization.

SITE OF VERNALIZATION

There are two sites of vernalization:

1. **Stem tip:** The localized cooling treatment was given to stem tip. It receives the vernalization effect. The stem tip is chilled. The rest of the plant may be kept at high temperature. It vernalizes all the plants.
2. **Meristem:** Lang in 1965, transplanted a vernalized meristem to unvernalized plants. The plant flowered. Then he grafted meristem from an unvernalized plant to a vernalized plant. Now the plant remained vegetative. Thus meristem is the site of vernalization.
3. **Seed:** Seeds are also vernalized before sowing. The embryo in seed receives the

vernalization stimulus. Then seed is sown. It produces flowers.

4. **Root tips and leaves:** The root tips and leaves of ***Lunaira biennis*** contain dividing cells. Therefore, its root tip and leaves can be vernalized. Thus, dividing cells are necessary for vernalization.

MECHANISM OF VERNALIZATION

Following views tried to explain the mechanism of vernalization:

1. Concept of Gregory

Gregory and coworker were working on cereals. They believed that vernalization process consists of several partial reactions. Cells within the shoot apex receives low temperature stimulus. It starts metabolic processes. These processes synthesize the flower stimulus. The flower stimulus is then transformed into localized areas within the shoot apex. Thus flowering start in it.

2. Hormonal Theory of G. Melchers

He suggested that low temperature induces the formation of **vernalin.** Vernalin is a growth substance. It initiates the synthesis of the flower stimulus. The vernalin has not yet been isolated. But some indirect evidence supports the existence of vernalin. G. Melchers performed two experiments:

(a) The grafting experiments of Melchers provide evidence about the existence of vernalin. He grafted a plant part, leaf or stem, of a vernalized henbane (Hyoscyamus) to a non-vernalized henbane plant. He found that the non-vernalised henbane flowered.

(b) Florigen also passes through graft union. Some physiologists suggest that florigen may be vernalization stimulus. The experiments of Melchers and Lang proved it wrong. They grafted an un-vernalized henbane (Hyoscyamus niger) plant to a Maryland Mammoth tobacco plant. The henbane plant flowered. The stimulus transmitted from tobacco plant to the henbane may be through photo inductive cycle or non-inductive cycles. Thus florigen is not produced in non-inductive cycles. Therefore, it cannot act as vernalin.

Chemical nature of vernalin

The low temperature treatment produces **vernalin**. This vernalin induces flowering. However, this hypothetical hormone vernalin cannot be isolated. But some plant physiologists believed that some plant growth hormone gibberellins may act as vernalin.

Evidence of gibberellins as a vernalin

(a) **Anton Lang** in 1957 applied gibberellins on biennials like henbane. Henbane require vernalization stimulus for flowering. Gibberellins induced flowering in it without cold temperature treatment.

(b) Purvis in 1961 induced flowering in winter annuals by treating their seeds with gibberellins.

(c) It was also found that the exposing of vernalization requiring species to low temperature treatment produces a large amount of natural gibberellins. These results indicate that properties of gibberellins are similar to vernalin.

Objections on gibberellins as a vernalin

Gibberellin was applied to vernalization requiring rosette plants. It causes elongation of stem. Then it produces floral buds on this shoot. In another experiment plants were provided cold temperature for inducing flowering. The floral buds appeared as soon as the shoot begins to elongate. Thus the effect of application of gibberellin and low temperature treatment are not same. It indicates gibberellin does not produce same affect as vernalin.

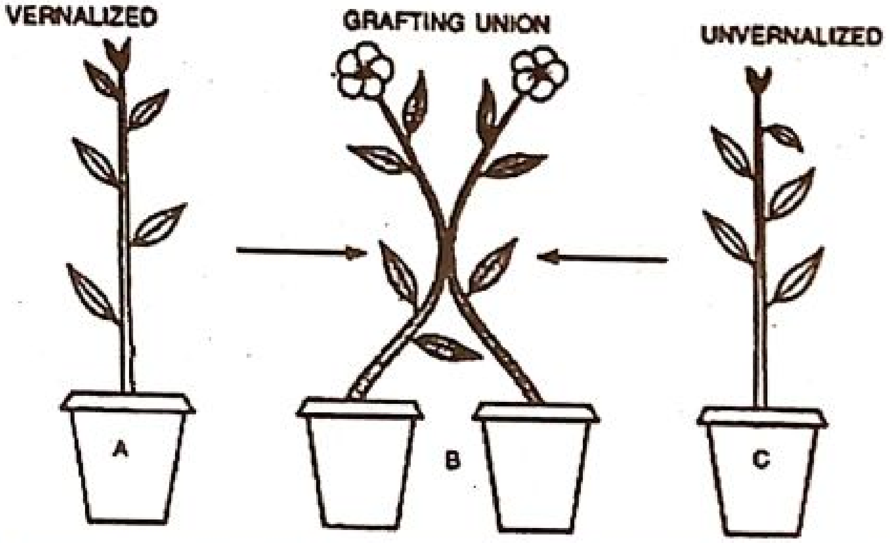


Fig. 5.7 Experiments to demonstrate that flowering stimulus can translocate from vernalized plant to unvernalized plant through graft union.

3. Anthesin hypothesis of Chailakhyan

Mikhail Chailakhyan (1968) suggested that two substances involved in flower formation. One is gibberellin or gibberellin-like substance and second is anthesin. Anthesin is hypothetical substance like vernalin.

Chailakhyan suggested that Vernalization requiring plants produce vernalin when subjected to low temperatures. The vernalin is then converted to gibberellins in long days. Gibberellin cause flowering in the presence of anthesin. But vernalin is not converted into gibberellin in short days. Therefore, flowering cannot occur in them. This hypothesis could not be proved experimentally.

4. Phasic development theory of Lysenko

Phasic development theory was put forward by a Russian plant physiologist **Lysenko**. According to this theory every plant passes through two phases of development. These phases are thermophase and photophase. Both these phases are controlled by environmental factors.

(a) **Thermophase: The early phase of life which requires definite temperature for development is called thermophase.** It is applied to development of seeds and seedlings. Each seed requires definite temperature. This requirement varies for different species. For example, biennial winter wheat need low temperature. But the seeds of annual spring varieties require higher temperature. Thermophase must be completed before the photophase. Thus chilled or vernalized seeds complete the thermophase.

(b) **Photophase: The late phase of life in which plant require definite light requirement for flowering is called photophase.** If the chilled seeds are sown, they grow and enter into photophase. This phase require definite light and dark period (photoperiodism) for flowering.

FACTORS AFFECTING VERNALIZATION

1. Water

Seed need to imbibe 20 -30% water. Therefore, dry seed cannot be vernalized. Petkus rye must imbibe water 50% of its absolute dry weight then vernalization starts.

2. Oxygen

Similarly oxygen is also necessary for vernalization. Oxygen is used during respiration. A germinating seed need energy. This energy is provided by respiration. The inhibition of respiration blocks the process of vernalization.

3. Temperature

The seeds are exposed to low temperature during vernalization. This temperature ranges from 1 – 7°C. Temperature lower than 4°C is not effective. Similarly, temperature above 12°C does not cause vernalization. The duration of vernalization varies in different species. It varies from 10 to 100 days. The period of 8 week is quite effective for vernalization in most of the species.

Lang performed experiments with henbane. It gives relationship between temperature and time of exposure for vernalization. He exposed henbane to different temperatures from 3° C to 17 °C. He exposed it for varying periods of time. Lang found that temperature range (3 to 17°C) is effective for period of vernalization is 105 days. The flower initiation occurred in 8 days. Then he shortens the vernalization period to 15 days. Now he found that different temperatures were effective differently. The most important was temperature 10 °C. It initiates flowers in 23 days. Then he extended the cold treatment period to 42 days. Now the most effective temperature range was from 3 to 6°C. It needs 10 days for flower initiation.

4. Devernalization

The exposing of vernalized seed to high temperature lost the effect of vernalization. It is called Devernalization. It occurs in case of sub-optimal vernalization. The temperature above 30 -35°C is effective for devernalization. However, the optimum vernalization cannot be devernalized.

5. Pre-vernalization growth

Age of the plant is also important for vernalization. Different species of plants have different ages for sensitivity to vernalization. For example, in cereals embryo can receive the stimulus of vernalization. But some biennial plants require a period of growth before receiving stimulus of vernalization. For example, *Hyoscymus niger* requires 10 days growth. Then it is verbalized.

6. Food substances

Food substances are required for respiration. Isolated embryos cannot be vernalized.

Some vegetative growth is necessary for plant. Then it becomes sensitive to low temperature. Thus some factor accumulates. This factor receives vernalization stimulus. This factor includes carbohydrates. These are synthesized during photosynthesis. In seedling stage, carbohydrates are stored during development of the embryo. Carbohydrates provide energy to seedlings during vernalization. Thus their presence is necessary for vernalization.

7. Effect of light

Light has no effect on the process of vernalization. Thus seed of a plant can be vernalized in the presence or absence of light. But many plants like carrot require both vernalization and photoperiodic stimulus. They must be first vernalized. Then these are given photoperiodic stimulus for flowering.

8. Effect of hormones

Many species like carrot and Hyoscyamus have obligate vernalization requirement. They are rosette in habit during vegetative stage. These plants show rapid flowering after vernalization. It also causes elongation or bolting in plant. The requirement of vernalization can be replaced by application of gibberellic acid. It causes both bolting and flowering.

OBJECTIVES

Fill in the blanks

1. Seed is given low temperature treatment during _______.
2. J. Gustav Gassner (1928) was working with _______
3. Winter Petkus rye is sown in the field in the _______ season of the year.
4. The spring Petkus rye is sown in the _______ season .
5. The plants which survive one growing season are called _______ plants.
6. The plants which survive two growing seasons are called _______ plants.
7. _______ in 1965, transplanted a vernalized meristem to unvernalized plants.
8. Gregory and coworker were working on _______.
9. G. Melchers suggested that low temperature induces the formation of _______.
10. The low temperature treatment produces _______.
11. Purvis in 1961 induced flowering in winter annuals by treating their seeds with _____.
12. Seed need to imbibe _______ water.

Ans: 1. Vernalization, 2. rye 3. fall 4. Spring, 5. Annual, 6. Biennial, 7. Lang , 8. Cereals, 9. Vernalin, 10. Vernalin, 11. Gibberellins, 12. 20 -30%

True/False

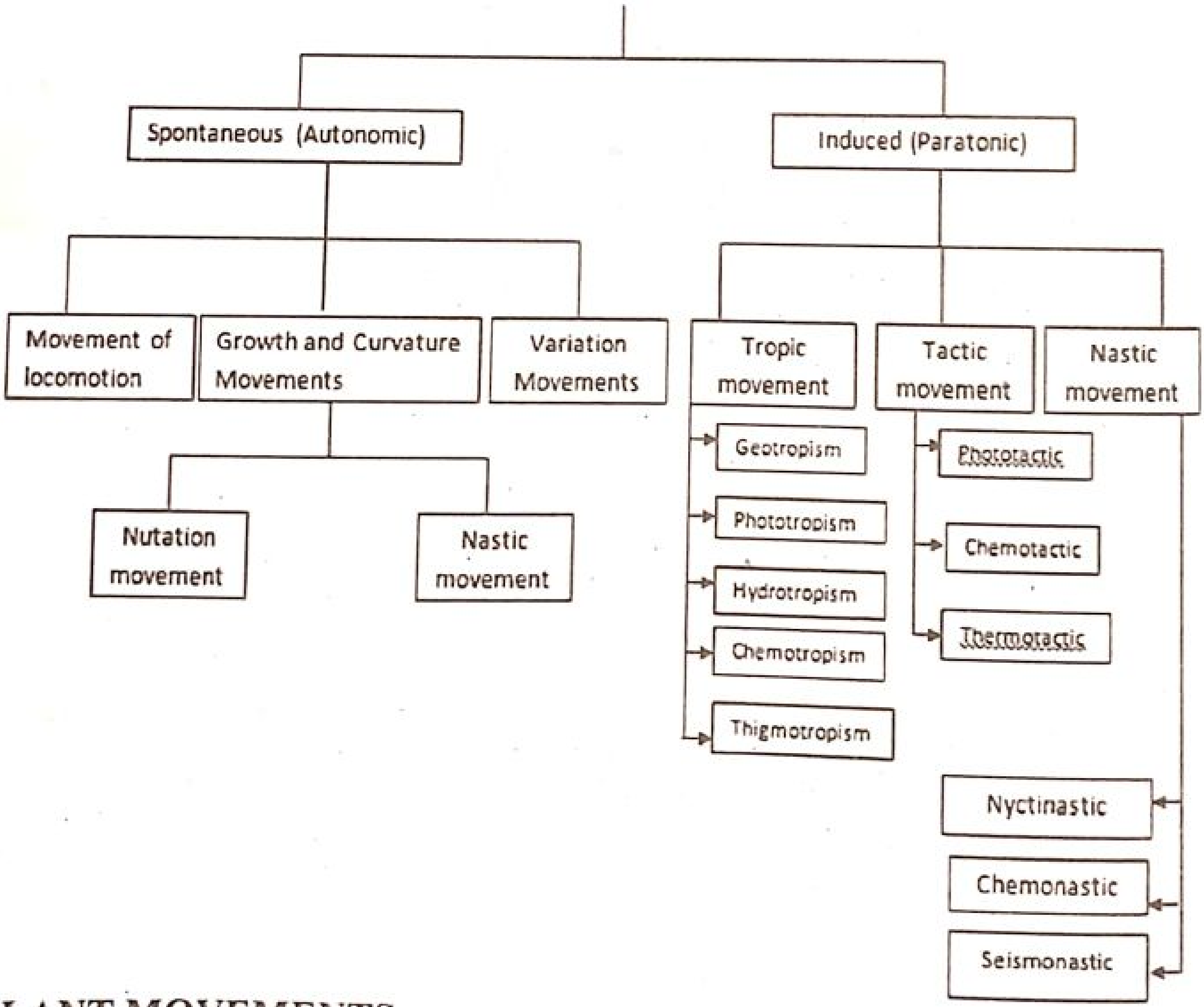
1. Seed is given low temperature treatment during vernalization.
2. Winter Petkus rye is sown in the field in the fall of the year.
3. The plants which survive one growing season are called biennial plants.
4. The plants which survive two growing seasons are called biennial plants.
5. Gregory and coworker were working on cereals.
6. The low temperature treatment produces auxins.
7. Purvis in 1961 induced flowering in winter annuals by treating their seeds with gibberellins.

Ans: 1. T, 2. T, 3. F. Annual, 4. T, 5. T. 6. F. vernalin 7. T

Chapter 12

PLANT MOVEMENTS

Syllabus
1. Tropic movements: phototropism, gravitropism and their mechanism
2. Nastic movements



PLANT MOVEMENT

PLANT MOVEMENTS

Movements are of universal occurrence in plants. Most of the plants are fixed. They can bend only their parts. It is called curvature movement. The locomotory movement of the animal type also occurs among plants. These are shown by free swimming organisms. For example, the ciliated algae like Chlamydomonas and Volvox, many bacteria and the reproductive cells of many algae, bryophytes, pteridophytes and some gymnosperms. In all these cases the entire organism moves from one place to another.

Most of the movements in plants are not rapid. Most rapid movement takes place in sensitive plant (***Mimosa pudica***). If a terminal leaflet of the plant is touched. All the leaflets at once close down in pairs and the entire leaf drops. The whole process takes a second.

There are two types of plant movements:

A. **Autonomic movement (Spontaneous movements):** The movements induced by some internal causes are called autonomic movement. It example is ciliary movement.

B. **Paratonic movement (Induced movements):** The movement induced by external stimuli is called Paratonic movement. Paratonic movement has three types: Tropic movement, nastic movement and tatic movements.

A. AUTONOMIC MOVEMENT (Spontaneous movement)

These are: Tactic movements, Turgor movement and Growth movement.

1. Tactic Movement

These are movement of the entire cell, its organelles or organism due to external stimuli. The tactic movements may be positive if these are toward the stimuli. These may be negative, if these are away from the stimulus. The tactic movements are further classified on the basis of nature of stimulus:

a) **Phototactic movement:** The tactic movement in response to stimulus of light is called phototactic. The movement may be toward the source of light, called **positive phototactic movement.** For example, positive movement of chloroplast due to cyclosis. This movement helps the plants to absorb maximum light for photosynthesis. The light intensity and direction of light affect the intra cellular distribution of chloroplast. It may move away from the source of light called **negative phototactic movement.**

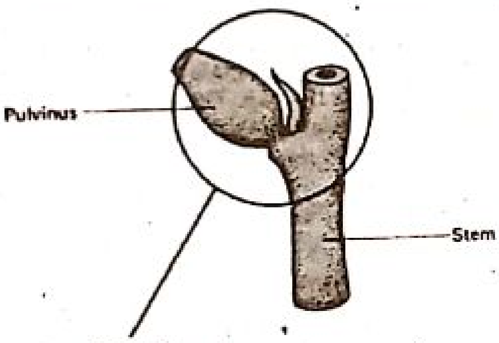
b) **Chemotactic Movements:** The movement in response to stimulus of chemical is called chemotactic movement. For example, the movement shown by sperm of liverworts, mosses, ferns. The sperm moves towards archegonia in response to nucleic acid stimulus.

2. Turgor Movements

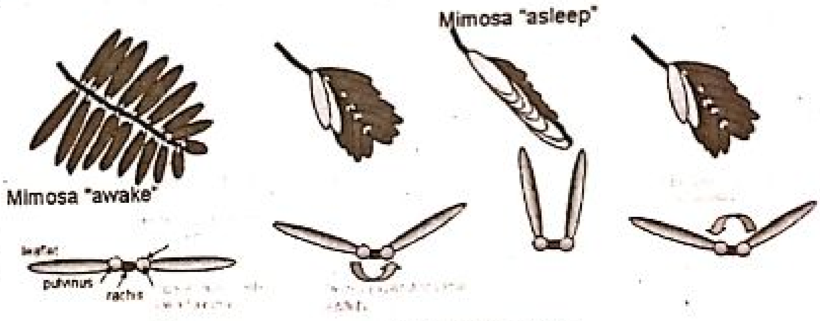
The movements due to differential changes in turgor and size of cells by gaining and losing water are called turgor movement. For example, rapid movement of leaflets in Touch Me Note and sleep movement of plants.

a) **Sleep Movement:** Some leguminous plants like bean lower their leaves in the evening and raise them in the morning. These are known as sleep movements. These sleep movements take place due to daily change in the turgor pressure in the **Pulvinus.**

The pulvinus is the swollen portion of petiole. It is composed of parenchymatous cells and central strand of vascular tissues. These parenchymatous cells have large intercellular spaces. The turgor pressure on the lower side of the pulvinus increases. So the leave rise and become horizontal. Similarly, turgor pressure decreases on the lower side of the pulvinus. So the leaves are lowered and it goes to sleeping position.



Pulvinus



Sleep movement in Mimosa

b) **Rapid movement of leaflets:** Mimosa (touch me not) have sensitive compound leaves. The leaflet of compound leaves fold together on touching. This response takes one or two seconds. The cells in pulvinus loss turgor rapidly. Investigation shows that potassium ion (K^+) moves out first. It decreases the osmotic pressure of the cells. So these cells lose water by exosmosis. The plant takes about ten minutes to regain the turgor and the internal turgidity of the leaves is restored.

3. Growth movement

The movements due to unequal growth on the two sides of plant organs like stem, root, tendrils are called growth movements. There are three types of growth movements:

a) **Epinasty:** It is shown by leaves, petals etc. In this case, the upper surface of the leaf shows more growth as compared to the lower surface in the bud condition. It causes opening of buds.

b) **Hyponasty:** In this case, the lower surface of the plant shows more growth as compared to the upper surface of the leaf in bud condition. Thus bud is remained closed.

c) **Nutation:** The growing tip of young stem moves in zig zag fashion due to alternate changes in the growth on opposite side of the apex. This mode of growth is called nutation.

B. PARATONIC MOVEMENTS (Induced Movements)

There are following types of paratonic movements:

1. Tropic Movements

The movements in curvature of whole organ towards or away from the stimuli such as light, gravity and touch are called tropic movement. Following are the common tropic movements:

a) **Phototropism: The tropic movement of the part of plant in response to stimulus of light is called phototropism.** It is caused due to differential growth of part of plant like root, stem or root.

b) **Heliotropism or solar tracking: The diurnal motion or seasonal motion of plant parts (flowers or leaves) in response to the direction of the sun is called heliotropism or solar tracking.** Its example is movement of flower head of sunflower in response to direction of sun.

c) **Thigmotropism: The tropic movement in response to stimulus of touch is called thigmotropism.** For example, climbing vines. When they come in contact with some solid object the growth on the opposite side of the contact increases. So tendril coils around the support.

d) **Chemotropism: The tropic movement in response to some chemical is called chemotropism.** The hyphae of the fungi are chemotropic.

e) **Hydrotropism: The tropic movement of plant in response to stimulus of water is called hydrotropism.** The growth of root toward water is due to positive hydrotropism. The shoot grows away from water. It is negative hydrotropic.

f) **Geotropism: The tropic movements in response to gravity are called geotropism.** Root show positive geotropism. But shoot shows negative geotropism.

g) **Aerotropism: The movement in response to air or oxygen is called aerotropism.**

2. Nastic Movement

The non-directional movement of the plant in response to external stimuli is called nastic movement. There are two types of nastic movement.

a) **Nyctinasty: The sleep nastic movements are called nyctinasty.** The nyctinastic movements are shown by the organs in response to external stimuli. These movements take place due to turgor and growth changes. It may of two types.

- **Photonasty:** The principle stimulus is the photoperiod for photonasty. The flower opens and closes due to light intensity.
- **Thermonasty:** The stimulus for thermonasty is temperature. There is rapid growth in the lower side of the petals of tulip flower at night. It causes upward and inward bending of petals. Thus flower of tulip close at night.

b) **Haptonasty: These movements occur in response to contact.** For example the action of the Venus fly trap.

TROPIC MOVEMENT (Detail)

The movements in curvature of whole organ towards or away from the stimuli such as light, gravity and touch are called tropic movement. It has different types. It may be phototropism, geotropism and hydrotropism.

(a) **Phototropism: The tropic movement of the part of plant in response to stimulus of light is called phototropism.** It is caused due to differential growth of part of plant like root, stem or root.

(b) **Heliotropism or solar tracking: The diurnal motion or seasonal motion of plant parts (flowers or leaves) in response to the direction of the sun is called**

heliotropism or solar tracking. Its example is movement of flower head of sunflower in response to direction of sun.

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(f) **Geotropism: The tropic movements in response to gravity are called geotropism.** Root show positive geotropism, while shoot show negative geotropism.

(g) **Aerotropism: The movement in response to air or oxygen is called aerotropism.**

PHOTOTROPISM

The tropic movement of the part of plant in response to stimulus of light is called phototropism. Almost all part of the plant shows phototropism.

1. **Stem:** A potted plant is placed in a dark room. Light is coming through a window. Its stem bends towards that window. Young stems are generally positively phototropic. They turn towards the light. The curvature is produced due to greater growth on the shaded side.
2. **Roots:** Most of the roots do not show phototropism. But some roots show negative phototropism e.g. mustard
3. **Leaves:** Leaves also show response to light. They twist their petioles and place their faces (upper sides) at right angles to the light. They are **diaphototropic or transversely phototropic**.
4. **Flowers:** Many flowers show positive phototropism. In Helianthus (sunflower) the flower heads face the east in the morning. It moves with the sun during the day and face west in the evening.

Demonstration of phototropism

A young seedling is grown in a phototropic chamber. It consists of a tight box. It has a removable lid. Its inner side is painted black. It has a glass window on one side. Therefore, light can enter only from this side. Phototrophic behaviour is studied on coloured screens. It shows that the maximum phototropic effect is produced in the blue violet end of the spectrum and the least in the yellow rays.

MECHANISM OF PHOTOTROPISM

(a) Role of coleoptile tip in phototropism

The germinating coleoptile of seedlings receives light from one direction. Their stems grow towards the light source. The side adjacent to the light source grows slowly. But the other side grows rapidly. This movement is called phototropism. The stem shows positive phototropism.

1. **Charles Darwin:** He performed experiment on oat coleoptiles. He exposed it to unilateral light. He found that tip of the coleoptile receive the stimulus of unilateral light. But growth response occurred from lower part of the stem. He concluded that stimulus is transmitted from the tip to the growth region.
2. **Boysen Jenson (1913):** They suggested chemical message moves from tip of coleoptile. They removed the tip of coleoptile. They placed a piece of gelatin between the tip and coleoptile stump. The stump curved towards light. Then they placed mica plate between the tip and stump. It is impermeable. The growth response was stopped. Now they placed mica sheet below the tip on shaded side. It developed a curvature. Then he placed mica sheet on illuminated side. The curvature did not develop.
3. **A. Paal (919):** He removed coleoptile tip. He placed it on one side of the cut stump. He found that rapid growth occurred beneath the tip. It produces a curvature. Paal concluded that hormone diffused from the tip. It accelerated the growth.

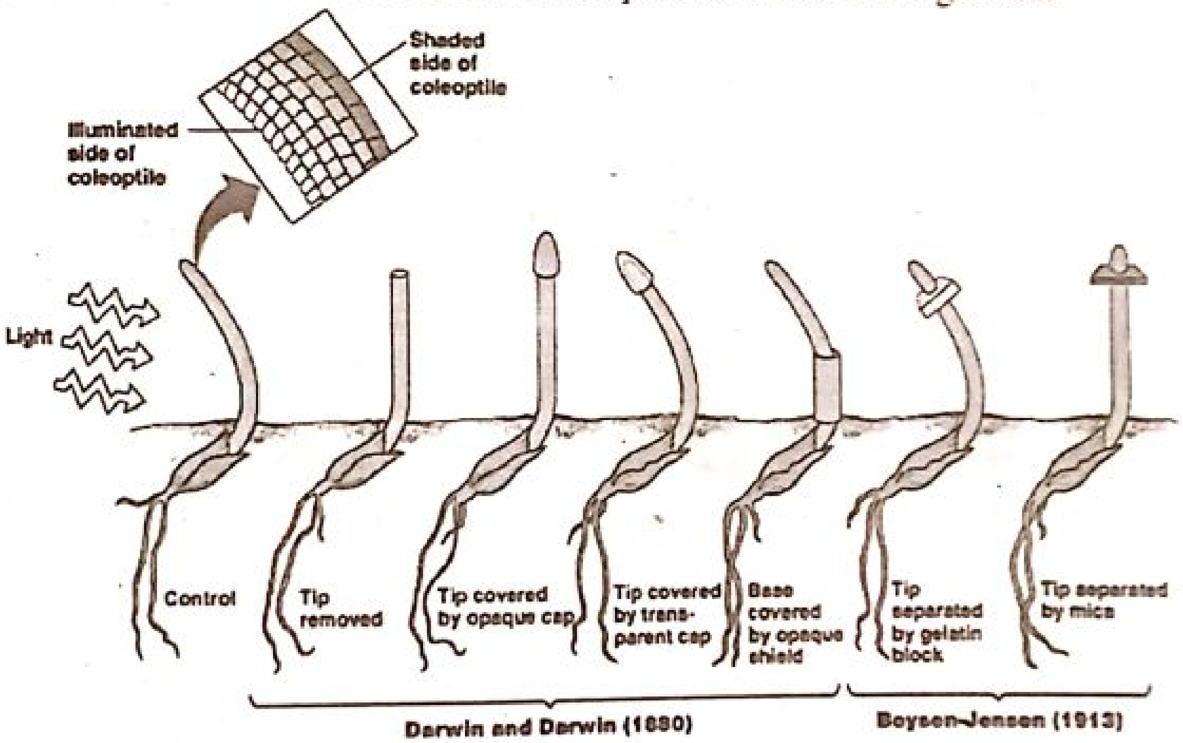

Shaded side of coleoptile
Illuminated side of coleoptile
Light
Control
Tip removed
Tip covered by opaque cap
Tip covered by trans-parent cap
Base covered by opaque shield
Tip separated by gelatin block
Tip separated by mica
Darwin and Darwin (1880)
Boysen-Jensen (1913)

Fig: Experiments of Darwin and Went

4. **Fritz Went (1928):** He carried out a series of experiments. He removed tips of dark-grown oat coleoptiles. He placed these tips on agar gel blocks. He kept these blocks in dark for several hours. He placed agar blocks on one side of the coleoptile stumps. It caused curvature in the coleoptile. Went concluded that agar block absorbed growth hormone from the coleoptile tip. When it was place on stump, it passed the hormone to the stump. Went named this hormone auxin (IAA). Auxin is synthesized in apical meristems and young leaves and then transported to the regions of growth in plant. It has highest concentrations at the tips of stems and roots, in young growing leaves, and in flowers and fruits.

(b) Role of auxin in phototropism (Cholodny –Went Theory)

Cholodny and Went theory suggested that the phototropic response occur due to

unequal distribution of auxin (IAA). Went removed oat coleoptile root tip. He placed it in two agar blocks. These blocks were arranged in such a way that one block received auxin from illuminated side and the other block received from shaded sides. He passed unilateral light on the excised tip. He found that more auxin was collected on the illuminated side.

Later experiments were performed on maize. It gives following observations:

1. The tips of coleoptiles were grown in dark light. They were cut and placed on agar blocks. It was found that 40 units of IAA diffused into the blocks in each case.
2. In other experiment the coleoptiles were split. Its two halves were separated by a thin glass cover slip. Same amounts of IAA were collected from the illuminated and darkened halves (20 units of IAA from each side).

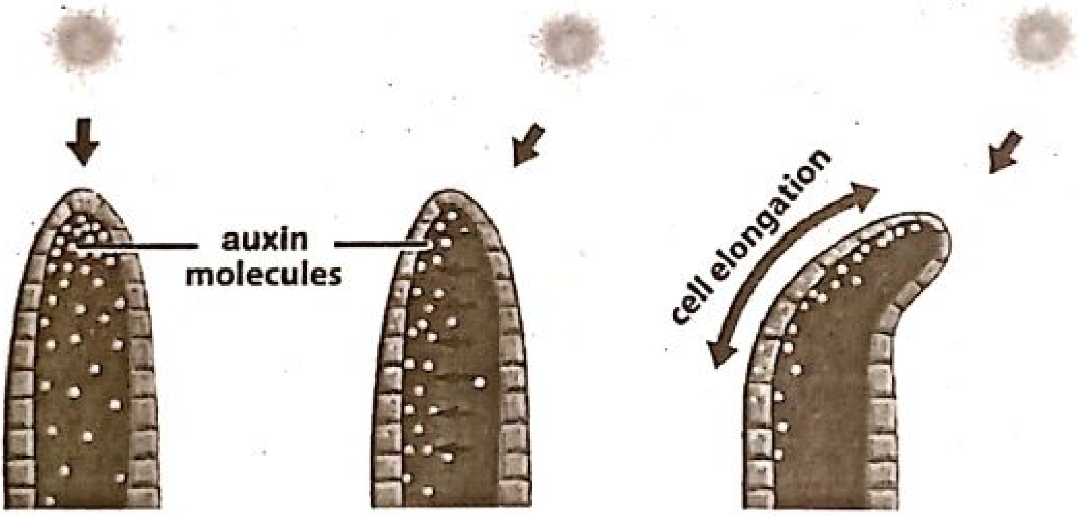


Fig: Experiments about distribution of hormone in coleoptile

3. Then the coleoptile was partially separated at the base by a thin piece of glass. Now more auxin diffused from the darkened half than the illuminated. About 30 IAA units collected from darkened half and 10 IAA units were collected from the illuminated half. These results suggest that unequal distribution of auxin causes phototropism.

(c) Role of Photoreceptor in Phototropism

Blue and yellow lights are most effective for phototropism. Thus two pigments are involved in the absorption of these lights. It is found that carotene and riboflavin receives light stimulus for phototropism. They are activated by light. Then they cause unequal distribution of IAA in stem or coleoptile tips.

GEOTROPISM OR GRAVITROPISM

The tropic movement in response to gravity of earth is called geotropism or gravitropism. The tip of the stem grows away from the gravity (negative geotropism) and the root tips grow towards it (positive geotropism). Unilateral gravity causes curvature in the region of elongation of stem and root. Geotropism can be demonstrated by simple experiments:

1. Seed of grams are soaked in water. Four soaked seeds are placed between two Petri

dishes in cotton. North, south, east and west are marked on the dishes. The dishes are fixed on a stand. The seeds are allowed to grow. After some days the position of dishes is changed. The stem and root shows curvature. It is found that the stem always move upward. Hence it shows negative geotropism. Root always bents downward. It shows positive geotropism.

2. Plant faces stimulus of gravity equally on revolving klinostat. Therefore, curvature is not caused in the tips of roots and stem.

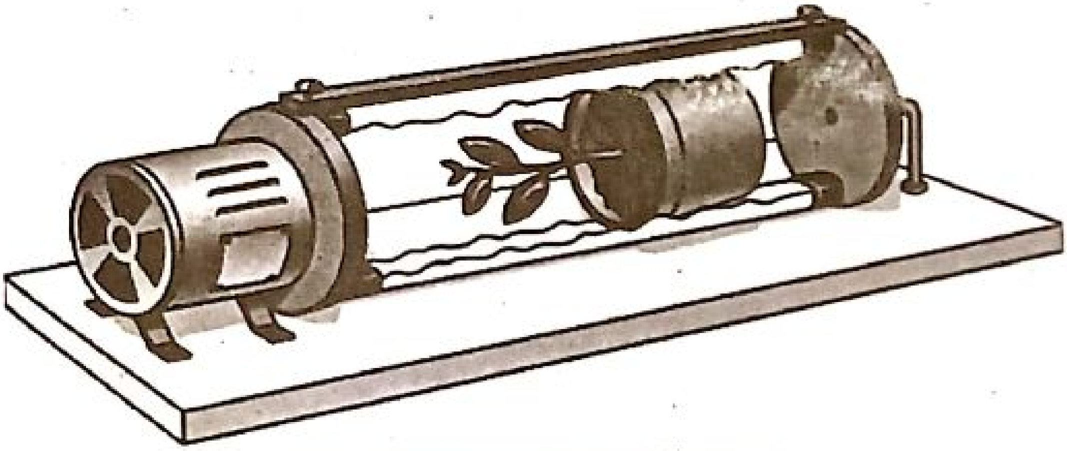


Fig: Experiment on Klinostat

Mechanism of Geotropism

It is believed that the stimulus of gravity is received by root cap. The root tips were removed from roots of pea. They did not respond to the gravity. It is believed that root cap produces an inhibitor on the lower side of the roots. It stops the growth and the root bends down.

(a) Cholodny Went Theory of Geotropism

This theory suggests that differential growth in geotropism is caused due to unequal distribution of auxin (IAA) in the upper and lower halves of the shoot. Auxin has following affects in stem and roots:

- **Stem:** The high concentration of auxin stimulates cell elongation in stems. More auxin accumulates on lower side. It increases the growth on lower side. Therefore, the stem curves upward.
- **Root:** High concentration of auxin inhibits the cell elongation in roots. Auxin accumulates on the lower side in a horizontally placed. Therefore, the root moves downward. Roots are much more sensitive to auxin than the stems. Ethylene is synthesized when auxin accumulates in root. It inhibits the root growth.

Current evidences show that the Cholodny – Went theory is not valid. The unequal distribution of auxin does not play much role in the geotropism.

(b) Statolith Theory of Geotropic Response

Cotlieb Haberlandt and B. Nemec proposed this theory. According to this theory the stimulus of gravity is received by **statoliths**. Statolith is specialized plastids called **amyloplasts. The cells containing amyloplasts are called statocysts.** These amyloplasts have large dense starch grains in them. The starch grains settle in the cells of the root cap in response to gravity and receive the stimulus of gravity. The statocysts are present in tips of coleoptiles, the root endodermis, and the sheath of vascular bundles of hypocotyls, epicotyls, and young foliage.

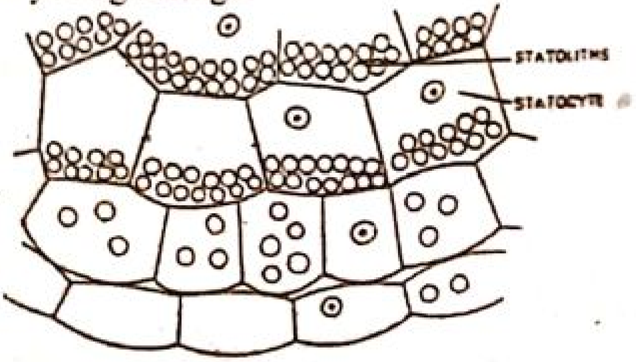
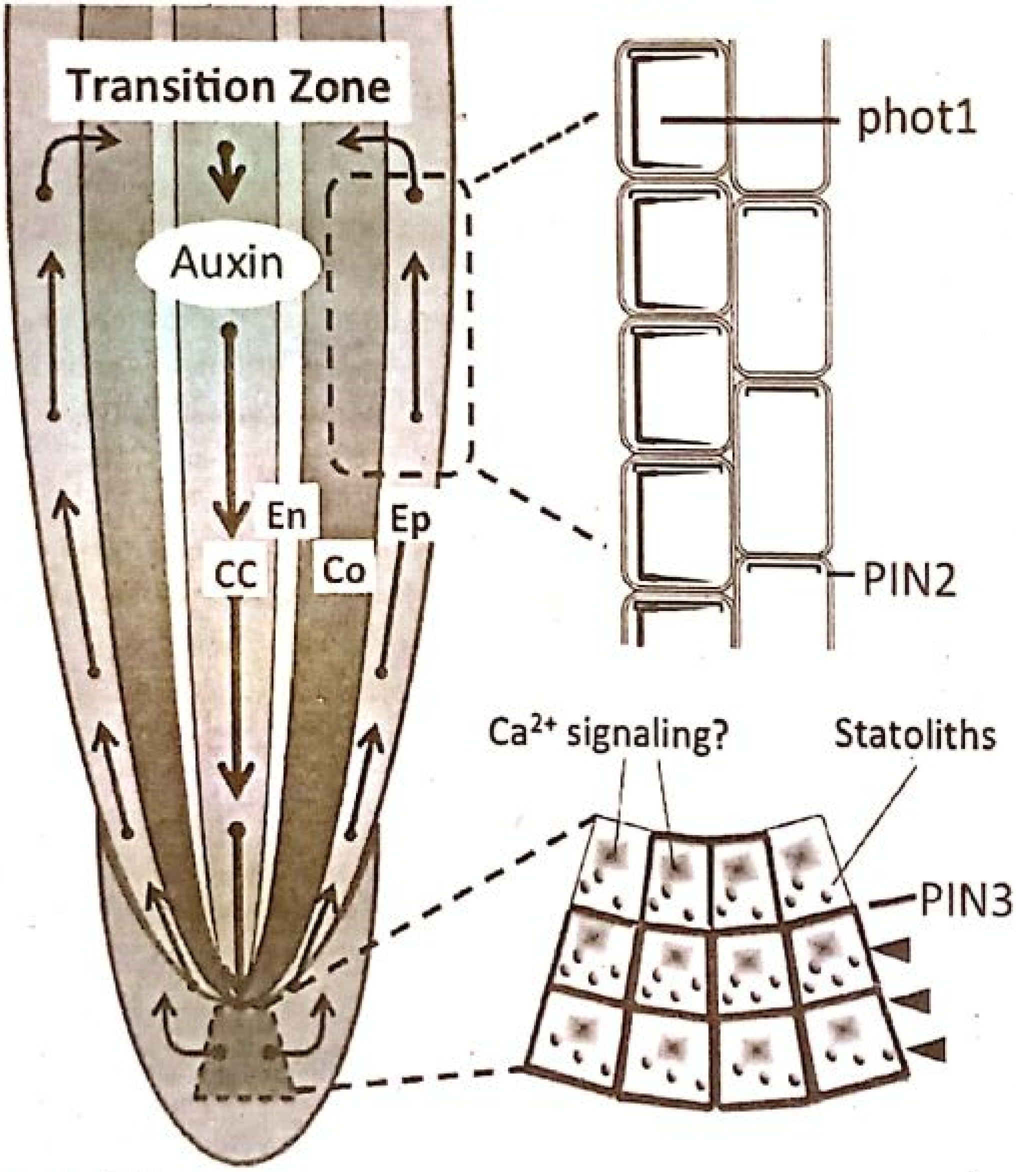


Fig: Statocysts containing statolith



Working of statolith

Statolith works in a following way:

1. This theory suggests that the plant moves from a vertical to a horizontal position. As a result the statoliths change their position in the cell.
2. The statoliths fall on the endoplasmic reticulum in a different part of the cell. ER releases calcium ions there. High concentration of calcium ions activates **calmodulin**. Calmodulin is a small protein present in the cells.
3. Calmodulin activates several enzyme systems. These enzymes activate the growth of the cell. Calmodulin switch on the pump for calcium ion and IAA present in the cell membrane. Calcium ions and IAA pass across the tissue of the stem or root from cell to cell. It increases or decreases growth in different regions.

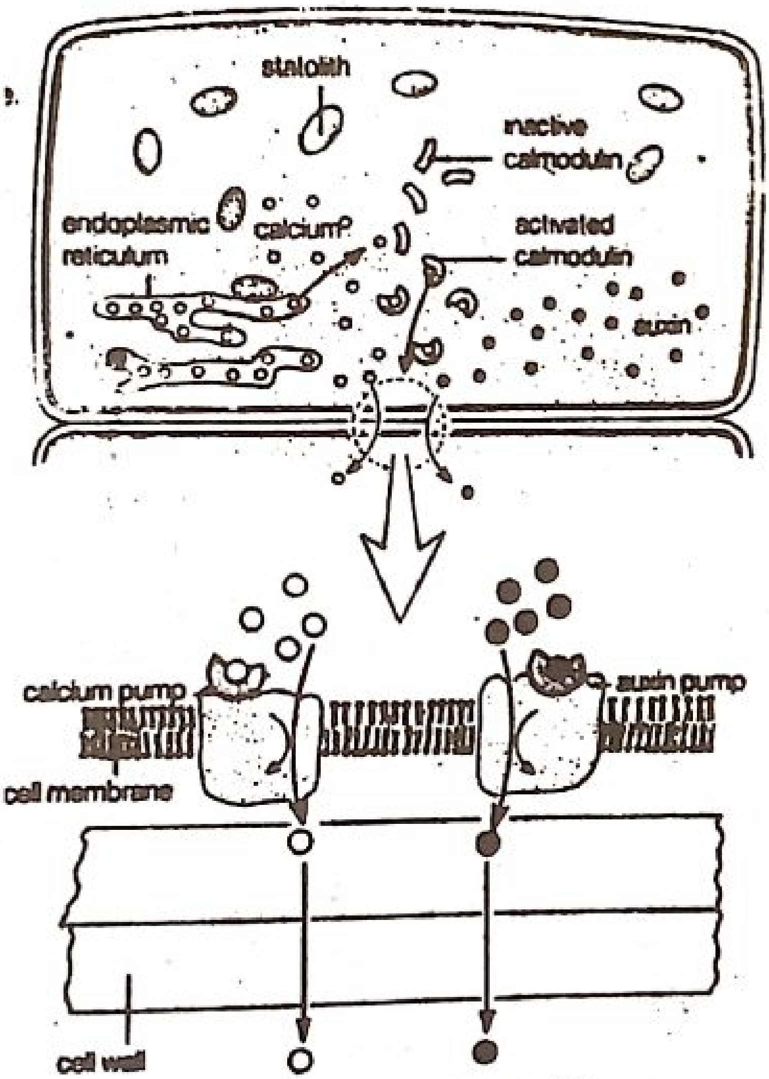


Fig: working of statoliths

Evidences in support of this theory

Following facts support the statolith theory of geotropic response:

1. Some mutant maize has smaller amyloplasts. They are less sensitive to the stimulus of gravity.
2. The treatment of coleoptiles with gibberellins and kinetin at high temperatures destroy the amyloplasts. Therefore, these stem and coleoptile do not respond to stimulus of gravity. The starch grains reappear in amyloplasts after sometime.

Therefore, the sensitivity reappears.

(c) Role of root cap in Geotropism (Inhibition theory)

The geotropism in root is inhibited with the removal of cap. It is restored with the regeneration of cap. Therefore, some plant physiologist believes that root cap regulates the geotropism. It has been proved by experiments.

1. In one experiment half of the root cap of maize root tip was removed. The root develops curvature toward the side of the remaining half cap.
2. The cap of maize root is removed. It increases the growth rate of its roots
3. In another experiment the maize caps are placed on the tip of lentil roots. It decreases root elongation.

These observations suggest that the root cap cells produce **abscisic acid**. Abscisic acid is a growth inhibitor hormone. It is transported into the elongation zone the action of gravity. It accumulates there and inhibit the cellular elongation on the lower side of the roots placed in a horizontal position.

NASTIC MOVEMENTS

The non-directional movements of the plant in response to external stimuli are called nastic movement. The variation in the intensity of some external factor acts as stimulus. The direction of the movement is determined by the structure of the plant organ itself. It is not determined by an external stimulus. Nastic movements occur only in bifacial organs like the leaves and petals. These organs can bend only in one direction. Nastic movements occur due to growth changes or movements of variation. There are following types of nastic movements:

(a) Nyctinasty or nyctinastic (sleep movements)

The diurnal movements are called nyctinastic or sleep movements. The flowers and leaves of many plants take up different positions during day and night. These movements are caused by alteration in light or temperature. Thus it has two types:

1. **Photonasty:** The principle stimulus of Photonasty is the photoperiod. The flower opens and closes due to light intensity. The flowers of Oxalis and the capitula open in the morning and close at night. But the flowers of some plants like evening primrose and Cestrum (night jasmine) open in the evening but closed in the morning.
2. **Thermonasty:** It takes place due to temperature changes. The flower opens when temperature is raised and closed when temperature is lowered. There is a rapid growth in the lower side of petal in the flower tulip at night. Thus it causes upward and inward bending of the petals. Thus the flower of tulip closes at night.

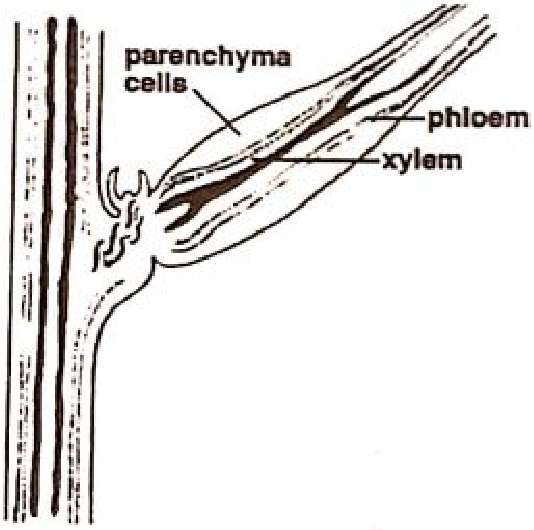
Mechanism of Nyctinastic movements

1. Growth

Growth curvatures cause nyctinastic movements. There is a increased growth on the inner or morphologically upper side (epinasty) of the petals. It opens the flower. There is increased growth on the outer or lower side (hyponasty). It closes the flower. The advantage of these movements to the plants is that their flowers open at a time when their pollinating insects are active.

2. Change in turgor pressure of pulvinus

Some leguminous plants like bean lower their leaves in the evening and raise them in the morning. These are known as sleep movements. These sleep movements take place due to daily change in the turgor pressure in the pulvinus. **The pulvinus is the swollen portion of petiole.** It is composed of parenchymatous cells and central strand of vascular tissues. These parenchymatous cells have large intercellular spaces. When turgor pressure on the lower side of the pulvinus increases, the leave rise and become horizontal. When turgor pressure decreases on the lower side of the pulvinus, the leaves are lowered and it goes to sleeping position.



(b) Seismonastic movements

The shock movements are called Seismonastic. It occurs in mimosa. When the leaves of Mimosa (touch me not) is touched, the leaflet fold together. This response takes one or two seconds.

These movements are caused by differential loss of turgor on the two sides of the pulvinus. The lower half the pulvinus is made up of thin walled cells. It has large intercellular spaces. The upper half the cells are comparatively thick walled. They have few intercellular spaces. There is following mechanism of these movements.

- The cells of both sides of the pulvinus are fully turgid during normal conditions. Therefore, the leaf is fully erect.
- The cells of the lower half lose water into the intercellular spaces on stimulation. Therefore, their turgor falls considerably. The cells of the upper half retain their turgidity. They even become more turgid by absorbing water from the intercellular spaces. Therefore, the upper turgid half of the pulvinus presses down the lower flaccid half. Thus the leaf droops.
- The cells of the flaccid half gradually reabsorb water from the intercellular spaces. Therefore, they regain their turgor and the leaf returns to its normal position after some time.

(c) Haptonastic or thigmonastic movements

The nastic movement occurs due to stimulus of touch are called Haptonastic movements. Haptonastic movements occur in the leaves of Drosera and Dionaea.

1. **Haptonastic movement in Drosera:** An insect flies on the marginal tentacles of Drosera. It stimulates the tentacles. Growth curvature occurs in the basal part of its stalk of the tentacles. Therefore, the tentacle bends towards the centre of the leaf. The direction of movements is determined entirely by the properties of the tentacle. Therefore, it is a nastic movement. It brings the insect in contact with the smaller central tentacles. The stimulus is transmitted to the other marginal tentacles. They

bend towards the insect from all directions.

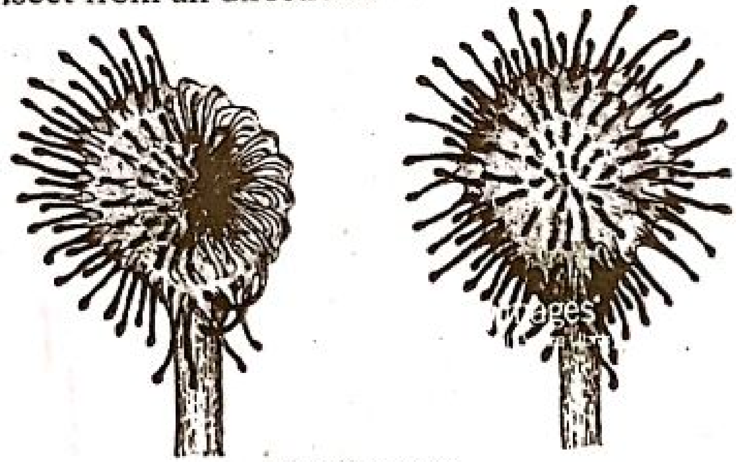


Fig: Drosera

2. **Chemonastic movements**: The tentacles of Drosera are also stimulated by ammonium salts, phosphates or a drop of water containing proteins. Therefore, tentacle of Drosera also shows **chemonastic movements.**
3. The one of the six sensitive hairs on the upper surface of the leaf is stimulated by contact. The two halves of the leaf close rapidly on the midrib. The midrib acts like a hinge.

DEFINITIONS AND KEY

TERMS	DEFINITIONS
Autonomic movement	The movements induced by some internal causes are called autonomic movement. It example is ciliary movement.
Paratonic movement	The movement induced by external stimuli is called Paratonic movement.
Tropic movement	The movements in curvature of whole organ towards or away form the stimuli such as light, gravity and touch are called tropic movement
Thigmotropism	The tropic movement in response to stimulus of touch is called thigmotropism.
Chemotropism	The tropic movement in response to some chemical is called chemotropism.
Hydrotropism	The tropic movement of plant in response to stimulus of water is called hydrotropism.
Geotropism	The tropic movements in response to gravity are called geotropism.
Cholodny and Went theory of photoperiodism	Cholodny and Went theory suggested that the phototropic response occur due to unequal distribution of auxin (IAA).
Cholodny and Went	This theory suggests that differential growth in geotropism is

theory of geotropism	caused due to unequal distribution of auxin (IAA) in the upper and lower halves of the shoot.
Statocysts	The cells containing amyloplasts are called statocysts.
Nyctinasty	The diurnal movements are called nyctinastic or sleep movements.
Pulvinus	The pulvinus is the swollen portion of petiole.
Seismonastic	The shock movements are called Seismonastic.
Haptonastic movements	The nastic movement occurs due to stimulus of touch are called Haptonastic movements.

MODEL SUBJECTIVE QUESTIONS

1. **Write note on tropic movement.**
2. **Write note phototropism. Give its mechanism.**
3. **Write note on geotropism. Give its mechanism.**
4. **Write note on nastic movement.**

SHORT QUESTIONS

1. **Differentiate between autonomic and Paratonic movements.**

Ans: The movements induced by some internal causes are called autonomic movement. The movement induced by external stimuli is called Paratonic movement.

2. **What is phototropism? How is it caused?**

Ans: The tropic movement of the part of plant in response to stimulus of light is called phototropism. It is caused due to differential growth of part of plant like root, stem or root.

3. **What is meant by diaphototropic?**

Ans Leaves also show response to light. They twist their petioles and place their faces (upper sides) at right angles to the light. They are **diaphototropic or transversely phototropic**.

4. **What is Cholodny and Went theory of phototropism?**

Ans: Cholodny and Went theory suggested that the phototropic response occur due to unequal distribution of auxin (IAA).

5 **What is Cholodny and Went theory of geotropism?**

Ans: This theory suggests that differential growth in geotropism is caused due to unequal distribution of auxin (IAA) in the upper and lower halves of the shoot.

6. **What are Seismonastic movements?**

Ans: **The shock movements are called Seismonastic.** It occurs in mimosa. When the leaves of Mimosa (touch me not) is touched, the leaflet fold together. This response takes one or two seconds.

7. **What are Haptonastic movements?**

Ans **The nastic movement occurs due to stimulus of touch are called Haptonastic movements.** Haptonastic movements occur in the leaves of Drosera and Dionaea.

OBJECTIVES

True/False

1. The movements induced by some internal causes are called _______movement.
2. The tactic movements may be _______if these are toward the stimuli.
3. The movements due to differential changes in turgor and size of cells by gaining and losing water are called _______movement.
4. The pulvinus is the swollen portion of _______.
5. In _______growing tip of young stem moves in zig zag fashion
6. The motion of plant parts in response to the direction of the sun is called _______.
7. The movement in response to air or oxygen is called _______.
8. The sleep nastic movements are called _______.
9. The cells containing amyloplasts are called _______.
10. High concentration of calcium ions activates _______.
11. Some mutant maize has smaller amyloplasts which are less sensitive to stimulus of_______.
12. The shock movements are called _______.
13. The _______half the pulvinus is made up of thin walled cells. It has large intercellular spaces.
14. The nastic movement occurs due to stimulus of touch are called _______movements.
15. The tentacles of Drosera are also stimulated by _______salts
16. The cells containing amyloplasts are called _______.
17. High concentration of _______ions activates calmodulin.

Ans: 1. Autonomic, 2. Positive, 3. Turgor, 4. Petiole, 5. Nutation, 6. Heliotropism, 7. Aerotropism, 8. Nyctinasty, 9. Statocysts, 10. Calmodulin, 11. Gravity, 12. Seismonastic, 13. Lower, 14. Haptonastic, 15. Ammonium, 16. Statocysts, 17. calcium

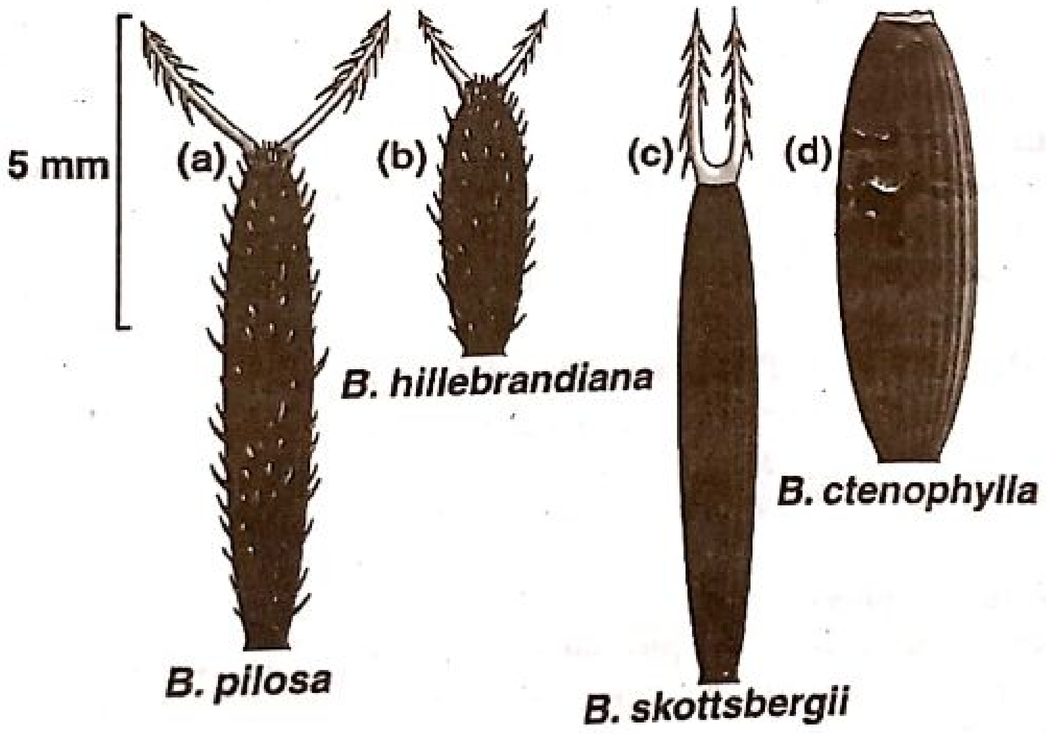
True/False

1. The movements induced by some internal causes are called autonomic movement.
2. The tactic movements may be positive if these are toward the stimuli.
3. The movements due to differential changes in turgor and size of cells by gaining and losing water are called growth movement.
4. The pulvinus is the swollen portion of petiole.
5. In nutation growing tip of young stem moves in zig zag fashion
6. The diurnal motion or seasonal motion of plant parts in response to the direction of the sun is called nastic or solar tracking.
7. The movement in response to air or oxygen is called aerotropism.
8. The sleep nastic movements are called nutation.
9. The cells containing amyloplasts are called statocysts.
10. Low concentration of calcium ions activates calmodulin.
11. Some mutant maize has smaller amyloplasts which are less sensitive to stimulus of gravity.
12. The shock movements are called Seismonastic.
13. The lower half the pulvinus is made up of thick walled cells. It has large intercellular spaces.
14. The nastic movement occurs due to stimulus of touch are called Haptonastic movements.
15. The hair of Drosera are also stimulated by ammonium salts
16. The cells containing amyloplasts are called statocysts.
17. High concentration of calcium ions activates calmodulin.
18. The shock movements are called nastic.

Ansers: 1. T. 2. T, 3. F. Turgor, 4. T, 5. T, 6. F. heliotropism, 7. T, 8. F. nyctinasty, 9. T. 10. F. High, 11. T, 12. T, 13. F. Thin, 14. T, 15. F. tentacles, 16. T, 17. T. 18. Seismonastic

PART B

PLANT ECOLOGY



Chapter 1

CONCEPTS OF ECOLOGY

ECOLOGY

The term ecology is derived from Greek words **oikos**, meaning the **"family household"**, and **logy**, meaning **"to study"**. This term was formed by the German zoologist **Erust Haeckel** in 1866. He called it **oecologic**. **Ecology is defined as the study of the relationship of organisms to their environment.** This relationship includes interactions with the physical world and with members of other species and the same species. The organisms are directly affected by the environment. Similarly activities of organisms try to change the environment.

Environment

The physical and biological conditions under which an organism lives is called environment. The environment may be organic or inorganic. Organic environment includes all the living organisms. Inorganic environment includes light, temperature, soil fire, wind etc.

SCOPE AND DEVELOPMENT OF ECOLOGY

Ecology is the study of distribution and abundance of organism. It includes the study of factors which control the number and location of the organisms. There are different levels of ecology. Interactions of the organism and environment take place in each level. These levels are:

1. Organismal ecology

It is also called autecology or physiological ecology. It is concerned with the behavioural, physiological and morphological ways of living of an organism. Each organism has certain limits of tolerance. These limits determine the habitat of the organism.

2. Population

The group of inter-breeding individuals belonging to same species and living in a common geographic area is called population. Population is the next level of ecology. The various kinds of organisms that inhabit an ecosystem make up populations. The populations of plants and animals do not function independently in an ecosystem. Some populations compete with other populations for resources such as food, water, or space. In some cases, one population is the food resources for another. Two populations may mutually benefit each other. A population can be described in terms of member, growth rate, and age distribution.

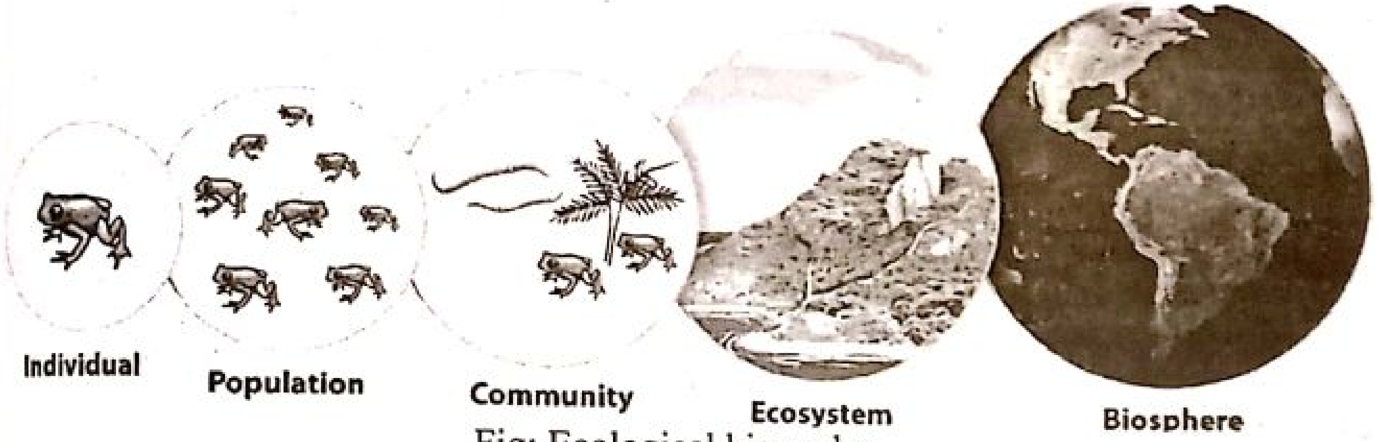


Fig: Ecological hierarchy

3. Community

All populations within an ecosystem are known as a community. The populations in a community are interconnected to one another. The individuals of these populations interact among themselves and with ~~individuals of~~ other species to form a community. The interactions are predation, competition, parasitism, commensalisms, mutualism and grazing.

4. Biomes

The major regional ecological community of plants and animals are called biomes. Each biome consists of different combinations of plants and animals. These plants and animals fully developed to form climax community. Each biome is characterized by a uniform life form of vegetation such as grass or coniferous trees. There are six major terrestrial biomes: Forest ①, Grass land ②, Wood land ③, Shrub land ④, Semi desert shrub ⑤ and Desert ⑥ ✓

4. Ecosystem ✓

A biological community together with the associated abiotic environment is called ecosystem. The ecosystem is a major unit of ecology. Organisms interact with their environment within an ecosystem. The **eco** part of the word related to the environment and the **system** part means a collection of related parts functioning as a unit. The study of ecosystem includes energy flow and cycling of the chemicals between biotic and abiotic components. The ecosystem consists of two basic interacting components:

(a) **Biotic component:** Biotic components consist of animals, plants, fungi, micro-organisms etc.

(b) **Abiotic components:** Abiotic components are atmosphere, climate, soil, and water.

TYPES OF ECOLOGY ②

) Autecology

he study of relationship of a single population to its environment is called utecology. For example, one person is studying the effect of water pollution on 50 to 00 plants of soybean on their growth and yield. As he is studying the single or one population of soybean plant, so this is autecology.

2. Synecology

The study of relationship of different communities or group of population to their environment is called synecology or community ecology. Growth responses of individual plant to environment are a complex factor. One factor increases the affect of other factor. These factors interact with one another. Complexity of environment depends on the combination of various factors. Following factors are studied in synecology:

(i) The various aspects of community like the origin, structure and composition of the community are studied in synecology. (علم حرکیات)

(ii) The history of community.

(iii) The dynamics of community because community is not a fixed entity. But different changes occur at different time.

(iv) Three levels of integration are studied in the community. These are: ① individual, ② population and ③ community.

BIOSPHERE

A thin layer of earth in which all living organism exist is called biosphere. Organisms within the biosphere are adapted to the environment. These organisms also interact to modify and control chemical and physical conditions of the biosphere. An organism lives in a habitat.

An organism responds to a variety of environmental factors. It can inhabit a location when all the environmental factors are within the range of its tolerance. Biosphere is characterized by two terms:

1. Habitat

The place where an organism lives is called its habitat. Habitat may be aquatic or terrestrial. Aquatic habitat may be marine or fresh water. Some organisms are parasites or symbionts. They live on other organism.

2. Ecological Niche

The basic role or profession of an organism in a community is called ecological niche. Niche is a distributional unit. The physical structure and physiological limitations keep species in this distributional unit. The study of niche includes: What an organism does in a community. What it does for living community. What are its relationship with its food and enemies? The niche is related to a profession or job of an organism. Thus the niche is particularly concerned with the:

(i) Feeding habits

(ii) The role of a particular species within an ecosystem

(iii) All aspects of its interaction with the living and non-living environment.

(iv) Ecological niche within a habitat also specifies how the organism gets its supply of energy and materials. For examples, predators-prey relationship of organisms and competition.

(v) Its behaviors and interactions in environment

(vi) Niche also includes all the physical environment factors necessary for survival, such as range of temperature, amount of humidity, the pH of the water and soil.

ECOLOGY AS AN EXPERIMENTAL SCIENCE

The humans always remain interested in other organisms and their environments. The prehistoric people were hunters. They had to learn where animals and plants were found. Many natural historians from Aristotle to Darwin observed and described organisms in their natural habitat. Thus the old natural history formed the basis of ecological science.

Ecology has a long history of being descriptive science. But most modem ecologists are skilled scientists. They perform different experiments. For example: There is question: The squirrels eat acorns plants. How does it affect the distribution and abundance of oak trees? Experiments are required to answer this question. These experiments require a large area of land from which squirrels can be removed. Another large area is required for controls. It also requires a long period of time in which to observe results.

Thus there is a great difficulty for conducting experiments in ecology. But still many creative ecologists are testing hypotheses in the laboratory. They are also experimentally manipulating populations and communities in the field.

Many ecologists also use mathematical models to answer ecological questions. Important variables and their relationships are described through mathematical equations. Computer is also used in the study of ecology. This is very useful approach. It allows the ecologists to conduct experiments in laboratory.

APPLICATIONS OF ECOLOGY

There are following applications of ecology:

1. Agriculture

Ecology has great applications in agriculture. Agriculture provides us food and fibers. Agriculture depends on ecological principles. These principles are limiting factors, irrigation requirement, pest control and productivity. Ecology helps to conserve the land. It helps to reclaim the alkaline and water logging soil..

2. Forestry

The study of forest is called forestry. The developing countries like Pakistan are facing problem of population explosion. This rapid increase in population growth increase requirements for food and shelter. Therefore man is cutting trees for agriculture and for wood used in houses. If the forests are continuously cut down at that rate, there will be no leaf canopy left. This leaf canopy protects the soil from driving rain. Consequently, some of the soil will run away with water and reach into the stream and river. This soil will be wasted. Thus the fertility of the soil will be reduced. There are three aspects of forestry:

(a) **Deforestations: Clearance of vast areas of forest for lumber, planting subsistence crops or grazing cattle is called as deforestation.**

(b) **Reforestation: The replantation of trees in a forest is called reforestation.** It is necessary that deforestation should be replaced with reforestation. Reforestation is especially important for many of the conifers species.

(c) **Aforestation: The establishment of new forests where no forests existed previously is called aforestation.**

Ecology helps in reforestation and aforestation. Ecologists are devising ways to stop deforestation, desertification and over grazing.

3. Wild life management

پالتو

All non-cultivated plants and non-domesticated animals are included in wild life. Wild life plays very important role in food chain. The food chain is disturbed without wild life. So, it becomes very difficult to maintain the balance in ecosystem without wild life. Man is trying to change the environment. The effects of these changes in environment are becoming more and more apparent with the passage of time. The imbalance in wild life can jeopardize the existence of man.

All living organisms are interdependent. A balance is present between living organisms and environment. Man is disturbing this balance since very long. **A species that is near to extinction is called endangered species.** Today there are thousands of endangered plants and animals. Wild life is a non-renewable resource. Ecologists are trying to save the endangered species.

· restore

4. Fishery and Aquaculture

The breeding and rearing of fishes is called fishery. The culturing of aquatic animals is called aquaculture. There is almost over fishing in rivers, lakes and seas. Therefore, population of fishes is decreasing in these water bodies. Ecological principles help to maintain population of fishes in rivers, ponds and lakes. The feeding habits, breeding physiology and habitat of fishes are studies. The fishes are cultured in ponds. They are given suitable nutrition and other ecological factors necessary for their growth. Oxygen is limiting factor in ponds. Therefore, oxygen is supplied artificially. Fishes are hatched in special hatcheries. These steps have increased the population of fishes.

5. Range land management

The grass land used by the animals for grazing is called rangeland. The application of science on rangeland for producing maximum number of grazing livestock regularly is called rangeland management. Rangeland has great importance for livestock development. Unfortunately, man has changed most of the rangeland into agricultural land. Therefore, fewer rangelands left in the country. These rangelands are needed to be protected from overgrazing. Overgrazing can change a rangeland into desert. The optimum utilization of rangeland maintains the rangeland. It also provides continuous supply of milk and flesh to humans. The maintenance of rangeland is one of the applications of ecology. Ecological studies tell us how much population of grazer a rangeland can sustain. It also tells us about the impact of destruction of rangeland on ecological cycle.

(آبپاشی)

6. Water shed management

An area from which water fall in the form of rain or snow collects into a stream and river is called watershed. The storage of water for irrigation and for producing electricity by constructing dams and barrages is called water shed management. Dams and barrages are back bone of our agriculture. Many dams are constructed all over the world. They have a lot of ecological impacts. There is need to study all these ([illegible])

ecological impacts before constructing a dam. Most the dams are facing the problem of silting. Silting is rapidly filling the dam. It is estimated that most of the dams in Pakistan will become useless within 10 year due to silting. Ecology helps to stop the silting process. Plantation of tree in water shed area can reduce silting.

7. Conservation of soil

Soil provides all essential contents to the plants. It provides water, mineral and oxygen to plant. All these contents are required in balance state. Soil erosion, alkalinity and water logging have badly affected the soil. Similarly, over cropping has reduced the nutrients of the soil. Ecology provides us the solution of all these problems. Soil erosion can be controlled by planting trees and keeping thick vegetation cover. Similarly, there are certain crops which can grow in alkaline soil. These crops reduce alkalinity of soil. Ecology has devised many methods to control water logging. The use of humus and crop rotation can maintain nutrient balance in the soil.

8. Control of pollution

The contamination of environment with harmful and unwanted chemicals is called pollution. Industrialization has destroyed our environment. These industries are producing a huge amount of industrial wastes. These wastes pollute our environment. The industrial waste contains a large amount of toxic and **carcinogenic** (cancer causing) materials. Automobiles and tanneries produce heavy metals like chromium. These metals affect our health.

Ecology helps us to control pollution. The ecologists are using the technique of bioremediation. The removal or the degradation of the environmental pollutants or toxic materials by living organism is called bioremediation.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Ecology	Ecology is defined as the study of the relationship of organisms to their environment.
Environment	The physical and biological conditions under which an organism lives is called environment.
Population	The group of inter-breeding individuals belonging to same species and living in a common geographic area is called population.
Community	All populations within an ecosystem are known as a community.
Biomes	The major regional ecological community of plants and animals are called biomes.
Ecosystem	A biological community together with the associated abiotic environment is called ecosystem.
Autecology	The study of relationship of a single population to its environment is called autecology.
Synecology	The study of relationship of different communities or group of

	population to their environment is called synecology or community ecology.
Ecological niche	The basic role or profession of an organism in a community is called ecological niche.
Deforestations	Clearance of vast areas of forest for lumber, planting subsistence crops or grazing cattle is called as deforestation.
Reforestation	The replantation of trees in a forest is called reforestation
Wild life	All non-cultivated plants and non-domesticated animals are included in wild life.
Watershed	An area from which water fall in the form of rain or snow collects into a stream and river is called watershed.
Water shed management	The storage of water for irrigation and for producing electricity by constructing dams and barrages is called water shed management.

MODEL SUBJECTIVE QUESTIONS

1. **Discuss scope and development of ecology.**
2. **Give types of communities.**
3. **Write note on ecological niche.**
4. **Discuss ecology as an experimental science.**
5. **Give different applications of ecology.**

SHORT QUESTIONS

1. **What is environment? What types of it are included?**

Ans: The physical and biological conditions under which an organism lives is called environment. The environment may organic or inorganic. Organic environment includes all the living organisms. Inorganic environment includes light, temperature, soil fire, wind etc.

2. **What is Organismal ecology?**

It is also called autecology or physiological ecology. It is concerned with the behavioural, physiological and morphological ways of living of an organism. Each organism has certain limits of tolerance. These limits determine the habitat of the organism.

3. **Define population.**

Ans: The group of inter-breeding individuals belonging to same species and living in a common geographic area is called population.

4. **Differentiate between community and biome.**

Ans: All populations within an ecosystem are known as a community. The major regional ecological community of plants and animals are called biomes.

5. **Differentiate between biome and ecosystem.**

Ans: The major regional ecological community of plants and animals are called biomes.

6. **Differentiate between biotic and abiotic components.**

(a) **Ans: Biotic component:** Biotic components consist of animals, plants, fungi, micro-organisms etc. and

(b) **Abiotic components:** Abiotic components are atmosphere, climate, soil, and water.

7. **Differentiate between autecology and synecology.**

Ans: The study of relationship of a single population to its environment is called autecology. The study of relationship of different communities or group of population to their environment is called synecology or community ecology.

8. **What is ecological niche? Which thing does it represents?**

Ans: The basic role or profession of an organism in a community is called ecological niche. Niche is a distributional unit. The physical structure and physiological limitations keep species in this distributional unit.

9. **Differentiate between deforestation and reforestation.**

Ans: Clearance of vast areas of forest for lumber, planting subsistence crops or grazing cattle is called as deforestation. The replantation of trees in a forest is called reforestation.

10. **What is range land and range land management?**

Ans: The grass land used by the animals for grazing is called rangeland. The application of science on rangeland for producing maximum number of grazing livestock regularly is called rangeland management.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. **The group of inter-breeding individuals belonging to same species is:**

(a) Habitat (b) population (c) community (d) Individual

2. **All populations within an ecosystem is:**

(a) Habitat (b) population (c) community (d) Individual

3. **The major regional ecological community of plants and animals are:**

(a) Biomes (b) population (c) community (d) Ecosystem

4. **A biological community together with the associated abiotic environment is:**

(a) Biomes (b) population (c) community (d) Ecosystem

5. **The basic role or profession of an organism in a community is called:**

(a) Synecology (b) Autecology (c) Niche (d) None

6. **The study of relationship of a single population to its environment is called:**

(a) Synecology (b) Autecology (c) Niche (d) None

Answers: 1. (b) 2. (c) 3. (c) 4. (d) 5. (a) 6. (b)

Fill in blanks

1. The physical and biological condition under which an organism lives is called __________.
2. The group of inter-breeding individuals belonging to same species and living in a common geographic area is called __________.
3. The major regional ecological community of plants and animals are called __________.

4. The study of relationship of a single population to its environment is called __________.
5. The study of relationship of different communities or group of population to their environment is called or community ________ ecology.
6. The basic role or profession of an organism in a community is called ecological __________.
7. All non-cultivated plants and non-domesticated animals are included in _________.
8. The grass land used by the animals for grazing is called ___________.
9. The application of science on rangeland for producing maximum number of grazing livestock regularly is called rangeland ________.
10. The study of forest is called ________.
11. The replantation of trees in a forest is called ________.
12. A species that is near to extinction is called ________species.
13. An area from which water fall in the form of rain or snow collects into a stream and river is called ________.
14. ________provides all essential contents to the plants.
15. The contamination of environment with harmful and unwanted chemicals is called ______ .
16. The place where an organism lives is called its _____.
17. The eco part of the word related to the __________.
18. ________part means a collection of related parts functioning as a unit.

Ans 1.environment 2. Population 3. Biomes 4. Autecology 5. synecology 6. Niche 7. wild life 8. Rangeland 9. Management, 10. Forestry, 11. Reforestation, 12. Endangered, 13. Watershed, 14. Soil, 15. Pollution, 16. Habitat, 17, environment, 18. System

True/False

1. The environment may be organic or inorganic. Organic environment includes all the non-living organisms.
2. Ecology is the study of distribution and abundance of organism
3. All populations within an ecosystem are known as a community.
4. The major regional ecological community of plants and animals are called ecosystem.
5. These plants and animals fully developed to form climax community.
6. A biological community together with associated abiotic environment is called ecosystem.
7. The eco part of the word related to the organisms.
8. System part means a collection of related parts functioning as a unit.
9. Biotic components consist of animals, plants, fungi, micro-organisms etc.
10. The study of relationship of a single population to its environment is called autecology.
11. The study of relationship of different communities or group of population to their environment is called autecology or community ecology.
12. A thin layer of earth in which all living organism exist is called biosphere.
13. The place where an organism lives is called its habitat.
14. The basic role or profession of an organism in a community is called ecological status.
15. The study of forest is called forestry. The developing countries like Pakistan are facing
16. The replantation of trees in a forest is called reforestation.
17. All non-cultivated plants and non-domesticated animals are included in natural life.
18. A species that is near to extinction is called extinct species.
19. The grass land used by the animals for grazing is called rangeland.

Ans: 1. F. living, 2. T, 3. T, 4. F. Biomes, 5. T, 6. T, 7. F. environment, 10. T, 11. F. synecology, 12. T, 13. T, 14. F. niche, 15. T, 16. T, 17. F. wild, 18. F. endangered, 19. T

Chapter 2

HISTORY OF ECOLOGY

Syllabus
Brief history of ecology (general and Pakistan)

HISTORY OF ECOLOGY

Man always has utilized environmental information. He uses it to collect food, trap animals, find edible plants and sow seeds. He uses it o harvest his crops in times and to migrate towards favourable habitat. The history of ecology is as old as the history of human civilization. The humans always remain interested in other organisms and their environments. The prehistoric people were hunters. They had to learn where animals and plants were found. Many natural historians from Aristotle to Darwin observed and described organisms in their natural habitat. Thus the old natural history formed the basis of ecological science.

1. Early Greek Philosophers

Early Greek philosophers and scientists knew the importance of environmental studies.

(a) **Hippocrates (460 B.C.):** He was taken as the father of medicine. He wrote about air, water and places. He advised doctors of his time to study the seasons and surroundings of their patients and correlate them with their diseases.

(b) **Aristotle (384 B.C.):** He discussed different kinds of animals and their habitats. He believed that adaptations in animals depend on their habitat and environmental condition.

(c) **Theophrastus (300 B.C.):** He is considered to be the father of Botany. He is also regarded a pioneer ecologist. He wrote about the plant communities. He also wrote about types of plants found in different habitats. These plants were land plants, aquatic plants, marine plants, marshy plants etc.

2. Role of Muslim Scientists in ecology

The western world was passing through dark ages in the mediaeval time. It was time of Muslim scientists' era. They did their researches in every field of knowledge. They also made a great contribution in the study of plants and their habitat. Regular experimental gardens existed in Cordova (Spain), Cairo (Egypt) and Baghdad (Iraq). These gardens were used for the study of plants. Following Muslim botanists worked on ecology:

(a) **Abu Mohammad Abdullah Ibn Ahmad Al Baiter (1197—1241 AD.):** He was famous botanist and great plant geographer. He traveled as herbalist in Spain, Greece, Italy, Asia Minor and North Africa. He described in detail, habit and habitat of 1,700 plants.

(b) **Abdul Latif:** He gave valuable botanical observations in his famous description of Egypt.

(c) **Abdul Abbas al Nabat:** He made botanical exploration in Spain and all along the African coast to Arabia.

(d) **Alberuni (941 A.D.):** He stayed in Indo-Pak subcontinent for fifty years. He studied the habit and habitat of plants growing in this region. He was the first man to describe the Indus plain was sea in the past. Later it was filled with alluvial soil.

(e) **Ibn-Wahshiya:** His book **Nabatean** gives detail of olive trees, springs and wells. It also gives the qualities of water and how to improve them. This book has also information about various plants and their possible varieties, changes in the atmospheric conditions; like vapour and wind, the causes of deforestation, the nature and improvement of soils, the cultivation of crops fruit trees and flowering plants.

3. Role of Western Ecologists in ecology

There is an expanding human population. It needs food and pollution free atmosphere. The understanding of environment is necessary for increasing food production and controlling pollution. A large number of ecologists are working on various aspects of environmental science in different parts of the world. Some of the important western ecologists are:

(a) **Linnaeus (1753 AD.):** He was a great systematic botanist. He described the plants and their distribution in relation to the nature of their habitat.

(b) **Von Humboldt (1810 A. D.):** He was a German ecologist. He made an important contribution in ecology in the beginning of the 19th century. He traveled widely in the world. He correlated the plant distribution on the earth with that of the climate.

(c) **Schow (1829):** He was a student of Von Humboldt. He discussed the effectiveness of light, temperature and moisture in species distribution.

(d) **Charles Darwin (1864):** He was naturalist. He traveled in a ship Beagle. He studied the habits, habitat and different adaptations in plants and animals in different regions.

(e) **Merriam (1894):** He was an American biologist He showed that North American flora and fauna are determined by environmental factors especially temperature.

(f) **Eugene Odum (1971):** He is one of the most famous modern ecologists. He worked on different ecosystem. He discussed the role of different environmental factors in the development of different communities in ecosystems.

4. History of ecology in Pakistan

Ecological study in Pakistan was started in recent times. Some research has been conducted on the problems of forest ecology in Pakistan Forest institute Peshawar. Some studies of ecological nature have also been carried out in the Punjab University. Autecological and synecological studies were made in Karachi University. The government of Pakistan has established following institutes to improve the ecological study and environmental standard:

(a) The government of Pakistan has established a federal ministry of environment and urban affairs in order to improve the human habitat in the country.

(b) The government has established Environmental protection Agency to the check the industrial pollution.

(c) Wild life department is working to save the wild life in the country

(d) In Karachi, a master plan environmental control department has been established, under the Karachi Development Authority. It is developing ways and means of providing a healthy environment to the citizens of Karachi.

(e) National Science Foundation is also playing an important role in improving the ecological knowledge.

Unfortunately, study of ecology has remained confined to government controlled institutes. We cannot get even a single Pakistani ecologist of international fame. Standard of working in ecology is also much poor in the country.

OBJECTIVES

Fill in the blanks

1. The prehistoric people were _______by profession.
2. Aristotle to Darwin observed and described organisms in their natural _______.
3. _______was taken as the father of medicine.
4. _______is considered to be the father of Botany.
5. Abu Mohammad Abdullah was famous botanist and great plant _______.
6. _______gave valuable botanical observations in his famous description of Egypt.
7. _______stayed in Indo-Pak subcontinent for fifty years.
8. Book of Ibn-Wahshiya _______gives detail of olive trees, springs and wells.
9. _______was a great systematic botanist.
10. _______was a student of Von Humboldt.
11. Charles Darwin traveled in a ship _______.
12. _______Odum worked on different ecosystem.
13. _______Science Foundation is improving the ecological knowledge.

Ans: 1. Hunters, 2. Habitat, 3. Hippocrates , 4. Theophrastus, 5. Geographer, 6. Abdul Latif, 7. Alberuni, 8. Nabatean , 9. Linnaeus, 10, Schow, 11. Beagle, 12. Eugene, 13. National

True/False

1. The prehistoric people were hunters.
2. Aristotle to Darwin observed and described organisms in their artificial habitat.
3. Hippocrates was taken as the father of medicine.
4. Theophrastus is considered to be the father of Botany.
5. Abu Mohammad Abdullah He was famous botanist and great plant geographer.
6. Abdul Latif gave valuable botanical observations in his famous description of USA.
7. Alberuni stayed in Indo-Pak subcontinent for fifty years.
8. Book of Abdul Latif Nabatean gives detail of olive trees, springs and wells.
9. Linnaeus was a great systematic botanist.
10. Charles Darwin traveled in a ship Beagle.
11. Eugene Odum worked on different ecosystem.

Ans: 1. T, 2. F. natural, 3. T, 4. T, 5. T, 6. F. Egypt, 7. T, 8. F. Ibn-Wahshiya, 9. T, 10. T, 11. T

Chapter 3

ECOPHYSIOLOGY

Syllabus

(a) Light and temperature responses
  (i) Quality of light
  (ii) Variation in light (temperature)
  (iii) Ecophyiological responses
(b) Edaphology
  (i) Brief introduction of soil forming process
  (ii) Texture, structure and water
  (iii) Chemical properties of soil
  (iv) Biological components: Soil organism, Organic matter
(c) Water
  (i) Precipitation, kinds and affectivity
  (ii) Distribution of vegetation in relation to moisture
(d) Wind: Ecological importance of wind

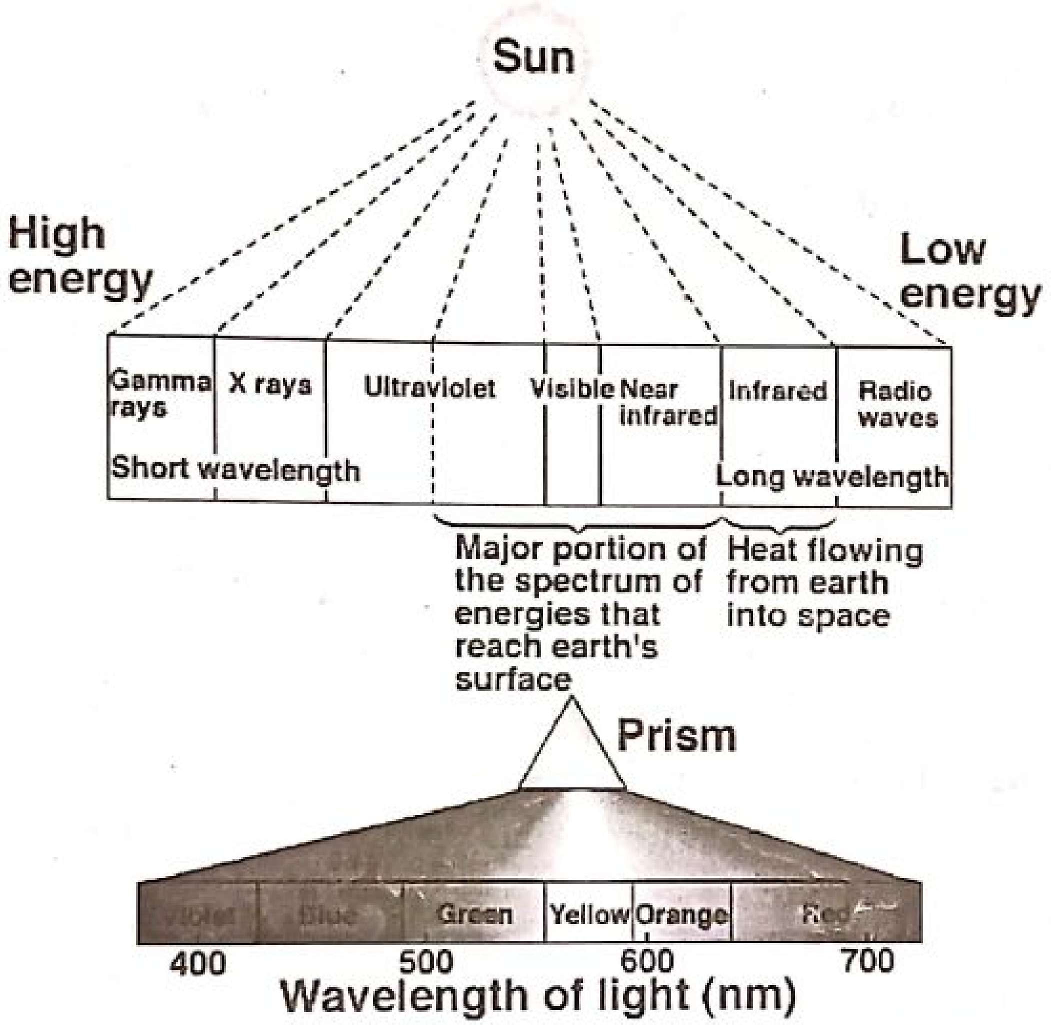
(a)LIGHT AND TEMPERATURE RESPONSES

QUALITY OF LIGHT

Sun provides all forms of energies in the earth. Solar energy reaches the earth in form of electromagnetic waves. The wave length of these waves ranges between 290-5000 millimicrons. The solar spectrum is divisible into visible and invisible spectra.

(a) Visible spectrum: The waves of visible spectrum bring most of the energy on the earth. It includes the wavelength between 400-750 millimicrons. Visible spectrum is divided into seven colours. These colours are red, orange, yellow, green, blue and violet. Different wavelengths (colours) play different role in the organism. For example, red and blue wavelengths are used in photosynthesis. Plants have different pigments for absorption of different wavelengths of different colours.

(b) Invisible spectrum: It has two parts: The wavelengths below 400 are called ultraviolet rays. Most of these ultraviolet rays are filtered by the ozone layers. The wavelength above 750 millimicrons is called infra red rays. These waves pass most of heat to the earth.



Classification of plants on the basis of requirement of light

There are morphological and anatomical differences between the leaves of plants growing in sun and in shade. There are also differences between sun-exposed leaves and shade exposed leaves of the same plants. Plants as a whole adjust themselves vertically towards the light. Therefore, the plants are classified ecologically on the basis of relative requirements of sunlight or shade. There are following categories of plants:

1. **Heliophytes: The plants which grow best in full sunlight are called heliophytes.** Heliophytes have thicker stem, short internodes, many branches, well developed roots, thick leathery leaves with more hairs per unit area. Intense light favours the formation of flowers, fruits and seeds. Mechanical tissues and xylem bundles are well developed. Leaf mesophyll is well differentiated into palisade and spongy parenchyma. The development of palisade parenchyma takes place near the upper surface of the leaf. It protects the inner tissues from intense light.
2. **Sciophytes: The plants which grow best at lower light intensities are called sciophytes.** Sciophytes have few branches and long stem. They have thin, large, etiolated and less hairy leaves. Cuticle of these leaves is thin. The palisade cells form few layers. Thin layered epidermis may contain chlorophyll. The spongy tissue is well developed with large intercellular spaces. Photosynthetic cells and mechanical

tissue are poorly developed in these plants. They have developed many adaptations for displaying their foliage to light. They may be twiners, climbers or epiphytes.

3. **Facultative Sciophytes:** The plants which grow best in sun but can also grow fairly well under shade are called facultative sciophytes.
4. **Facultative Heliophytes:** The plants which although grow best at lower light intensities but can also grow well in full sunlight are called facultative heliophytes.

Ecophyiological responses of light

Light is a factor of great ecological importance. It has following ecophyiological responses:

1. Photosynthesis

It is responsible for synthesis of food by green pigment. Only about 2% light is used in photosynthesis out of the total solar energy reaching the earth. 10% energy is used in other physiological activities. Green plants manufacture carbohydrate from water and carbon dioxide during the process of photosynthesis in presence of sunlight. The solar radiations provide energy for this process. Thus the radiant energy of the sun is converted into the chemical energy by chlorophyll. The chemical energy stored in food is utilized in various other biochemical activities in the plants.

2. Opening and closing of stomata

Stomata of the leaf open in the day and close in the night. Light convert starch of the guard cells into sugars. Sugar increases their osmotic pressure. It increases suction pressure in guard cells. Thus water flow into them. It increases the turgidity of the guard cells. Therefore, it causes the opening of stomata. Stomata are used for gaseous exchange and transpiration.

3. Photoperiodism

The response of plant to 24 hour day night cycle is called photoperiodism. Photoperiodism affects the vegetative growth and flowering of the plants. Plants are divided into three groups on the basis of photoperiod

(a) **Short day plants:** The plants that develop flower only when the photoperiod less than a critical length are called short day plants. For example tobacco plant.

(b) **Long Day Plant:** The plants that develop flower only when the photoperiod, more than a critical length are called long day plants. For example Hyoscyamus.

(c) **Day neutral plants:** They are not affected by photoperiod. For example tomato

4. Development of chlorophylls

Light is essential for development of chlorophylls. If plant is kept in darkness, its leaves become yellow and losses chlorophylls. This phenomenon is called **chlorosis.** The chlorophylls of some leaves are lost at different places. Such leaves are called **etiolated leaves.**

5. Germination of seed

Some seeds may germinate in darkness. But light is necessary for the germination of some seeds. They are called photoblastic seeds. Light requiring seeds are placed in light before sowing. They get the light stimulus. Then they are sown and they germinate easily. For example seeds of carrot.

TEMPERATURE (VARIATION IN LIGHT)

Temperature is one of the most important ecological factors. It regulates many physiological processes of the plant. The metabolic processes are low at a certain minimum temperature. It increases at particular temperature called optimum temperature. The plant grows best at optimum temperature. Metabolism again decreases at maximum temperature. The plants cannot survive above this temperature. Both extremely low and high temperatures have adverse effect on plant growth.

1. **Low temperature:** Low temperature causes cold injuries. Water is frozen into ice crystals in the intercellular spaces. It causes injury to cells.
2. **High temperature:** Extremely high temperature cause adverse effects on a number of vital physiological processes like respiration, transpiration, protein metabolism etc. These effects cause stunting and finally death of plants. This is called as Heat Injury.

Different kinds of plants have various ranges of minimum-optimum-and maximum temperatures. Plants differ considerably in temperature tolerance. Generally, there is little metabolic activity at temperature below 0°C or higher than 40°C. However some arctic and alpine plants can carry on photosynthesis at temperature below freezing point. Numbers of plants are active at temperature above 40°C. Some arctic and alpine plants die even at moderately warm temperatures. But almost all seed plant become inactive or killed after 55°C. On the other hand a few kinds of blue-green algae can grow in hot springs between 55-70°C. Certain species of yeast can tolerate temperature of 114°C in dormant conditions. Bacteria can tolerate temperature between 120-130°C. A few fungi can withstand temperature up to 89°C.

Temperature classification of plants

The plants are classified into the following categories on the basis of temperature requirements.

1. **Megatherm:** The plants live in high temperature throughout the year are called megatherms. These plants are found in equatorial and tropical rain- forests.
2. **Mesotherm:** The plants living at high temperature of summer, alternating with low temperature of winter are called mesotherms. They are found in deciduous forest of tropical and subtropical regions.
3. **Microtherm:** The plants which live in extremely low temperature are called microtherms. It includes plants of temperate and high altitudes (upto 12000 feet of tropical and subtropical region). These regions are dominated by mixed Coniferous forest.
4. **Hekiskotherm:** It includes plants of Arctic and Alpine regions (above 16000 teat in tropics and 12000 feet in temperate) with very low temperature. Alpine vegetation prevails in such locality.

Ecophyiological responses of temperature

Temperature is an ecological factor. It affects the rate of many physiological processes in plants.

1. Transpiration

Temperature affects the saturation deficit of the air. So it has an indirect influence on the rate of transpiration. Rise in temperature decrease the relative humidity of the air. It increases the rate of transpiration. Low temperatures decrease the capacity of the air to hold moisture. Therefore, it increases the relative humidity. It decreases the rate of transpiration. High temperatures also open the stomata widely. It increases the transpiration. High rate of transpiration also increases the rate for absorption of water from the soil.

2. Photosynthesis

A suitable temperature is necessary for photosynthesis. Photosynthesis occurs over a wide range of temperature. In some desert plants photosynthesis continues even at 80°C. Most of the algae require lower temperature range for photosynthesis than the higher plants. The optimum temperature for photosynthesis for most of the plants is 25 to 35°C. Photosynthesis stops at 40°C in temperate plants and at 50°C in tropical plants. There are three cardinals of temperature for photosynthesis.

(a) **Minimum:** It is minimum temperature at which the photosynthesis starts. Minimum temperature for many lichens is - 20°C. It is -35° C for some conifers. Photosynthesis hardly starts at about 5°C in tropical plants. Desert plants like cactus can carry on photosynthesis even at 55°C

(b) **Optimum:** Maximum photosynthesis occurs at that point. The optimum temperature also varies greatly. Photosynthesis increases with rise in temperature up to 25°C. This increase follows **Vant Hoff's law**. According to this law the rate of chemical reaction doubles for every rise of 10°C.

(c) **Maximum:** It is the highest temperature at which photosynthesis can take place. There is an initial increase in the rate of photosynthesis at this temperature. But this is soon followed by a decline. Higher the temperature the more rapid is the decline. The decline may be due accumulation of photosynthetic products, inhibition of enzymes at high temperature or destruction of chlorophyll.

3. Respiration

The rate of respiration increases with the rise of temperature. It is maximum at optimum temperature. But it decreases rapidly above optimal temperature. Plants obtain most of energy from photosynthesis at day time. Therefore, respiration rate is lower at day time. But at night time, plants obtain energy by respiration. Therefore, rate of respiration increases at night time. Temperature does not affect much at night time on respiration.

4. General distribution of plants

Temperature and moisture determine the general distribution of vegetation. Different belts of vegetation occur between the equator and the poles. Vegetation is primarily determined by heat. Thus plants which grow in a hot climate cannot grow in a cold climate and vice versa. Therefore, same crop are not cultivated in all regions of the world. Different crops are cultivated in different regions of the world.

5. Germination of seed

Temperature also affects the germination of seed. Every seed has optimal temperature. Seed cannot grow below or above this temperature.

6. Growth

Temperature influences the rate of growth within a certain range (0-35°C). Normally, rate of growth increases with increase in temperature. But it decreases with decrease in temperature. The optimum temperature is 25-30°C for maximum growth. The growth is minimum at 5 -10°C. But the growth stops at a very high temperature (35-40°C). The plant may dies at this temperature.

7. Rate of enzyme action

The rate of reaction may increase with the increase in temperature. But this increase is up to a certain limit. All enzymes can work at their maximum rate at specific temperature called optimum temperature.

Heat provides two types of energies:

- **Activation energy:** Heat provides activation energy. Activation energy accelerates the chemical reactions at high temperature.
- **Kinetic energy:** Heat also supplies kinetic energy to molecules. Therefore, the reactant molecules move rapidly. Thus the chances of their collision with each other are increased and they easily react with each other.

However, further increase of heat energy also increases the vibrations of atoms of the enzymes molecules. Now the vibrations become too violet. As a result globular structure is lost. This globular structure is essential for the activity of the enzymes. Such enzyme is called denatured.

8. **Spreading of diseases:** Temperature and humidity affects the spreading of plant diseases. Low temperature along with high humidity favours the attack of rust, damping off, seedling blight, foot rot and root rot.

9. **Absorption of water:** The rate of water absorption increases with a rise in soil temperature. But this rise to a limit. Temperatures above 35°C affect the permeability of the plasma membrane and decrease water absorption. Lowering of soil temperature greatly reduces water absorption. Cold soils are, therefore, physiologically dry. Some of the more important causes of decreased absorption at low soil temperatures are as follows:

- Low temperature increases the viscosity of water.
- Low temperature decreases the rate of root elongation.
- Low temperature reduces the metabolic activity of the living cells of the roots.

(i) ✓

(b) EDAPHOLOGY

EDAPHOLOGY (Int —)

The weathered layer of the earth crust is called soil. Typically soil is made up of parent material. Organic matter and living organisms incorporate into it. The spaces remaining between the solid particles are filled with water and gases.

Plants are anchored in the soil. Soil is a source of nutrients for them. It also acts as a great reservoir for the water. The plants absorb water from the soil. It is also a source of oxygen for the respiration of soil microorganism and the roots of the higher plants. The solid portion of most soils remains fairly constant in volume. But the pore space between solid particles may be completely filled with water after rain. Most plants grow best where soil pore spaces are not occupied by water or air.

Braches of Soil science

Soil science is used to study different parameter of science. There are two branches of soil sciences: edaphology and pedology.

(a) **Pedology: The study of soil in their natural environment is called pedology.** Pedology deals with pedogenesis, soil morphology, and soil classification.

(b) **Edaphology: The study of influences of soils on living things, particularly plants is called edaphology.** It gives the information how soil influences use of land for plant growth. It also tells about man's overall use of the land. General sub-fields of edaphology are agricultural soil science (agrology) and environmental soil science.

PROCESS OF SOIL FORMATION

Soils consist of small fragments of mineral matter. These minerals are derived from solid rocks. This solid rock is present beneath the surface of the earth. A rock is an aggregation of minerals. There are different aspects of soil formation. These are:

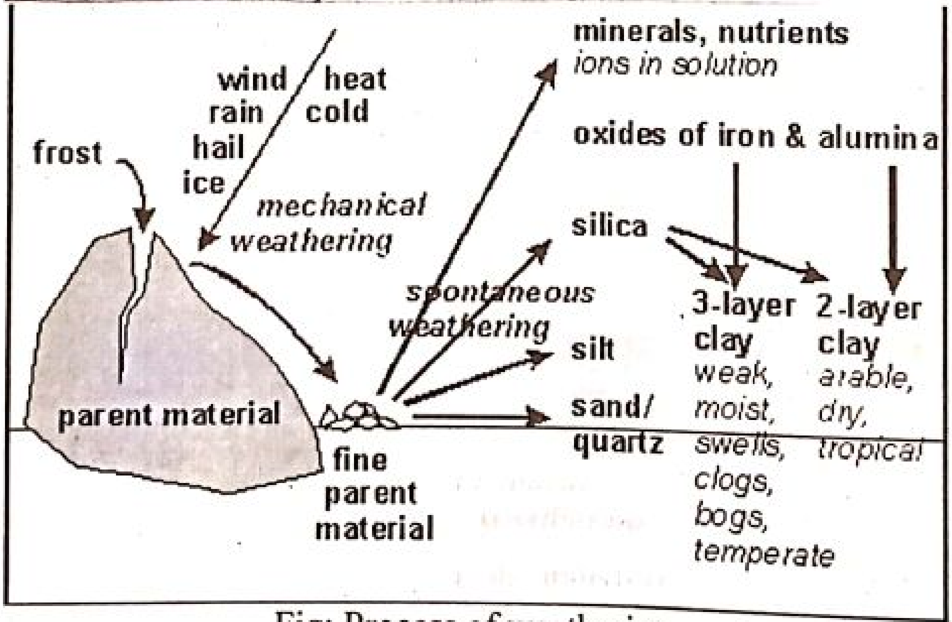


Fig: Process of weathering

(A) WEATHERING

The breakdown of soil is called weathering. There are ~~two~~ (3) types of weathering: mechanical weathering, chemical weathering.

(a) Mechanical Weathering

The breakdown or disintegration of the rock, by cracking through various agencies is called mechanical weathering. The rate of breakdown depends on the nature of the rock material. It is slow on igneous rocks like granite and basalt. Salty and limestone rocks are broken down readily. The agencies or forces of mechanical weathering are: Temperature, Rain water, Snow, Wind, plants and animals.

1. **Temperature:** Fluctuations of temperature influence the disintegration of rocks. Rocks expand on heating and contract on cooling. It causes carks in the rocks. Thus the rock is broken down into fragments. Freezing and melting of water further increase weathering. Water expands on freezing. It exerts great pressure and breaks the rock.
2. **Rain Water:** Rain water brings down the fragments of rocks from the slopes. Water with these fragments has tremendous cutting power. Thus it cuts the rocks over which it flows.
3. **Snow:** Snow move down the rocks from glaciers. It grinds the underlying the rocks. They also mix the mineral fragments of different types.
4. **Wind:** Wind carries small fragments of the rocks from one place to the other. The fragments strike on the rocks. They cut the rock material.
5. **Plants and animals:** Plant roots grow into the rocks. It developers cracks in the rocks. Finally, it breaks the rock. Similarly burrowing and hoofed animals also disintegration of rocks.

✓(b) Chemical Weathering

New minerals are formed during chemical reactions. Some minerals are decomposed and disappear. It leaves more resistant minerals behind. Such processes are called chemical weathering. It commonly occurs in humid regions. Following process take place during chemical weathering:

1. **Hydrolysis:** The process of decomposition with the help of water is called hydrolysis. Many minerals like feldspar-s and mica are broken down by this action.
2. **Hydration:** In this case, H and OH ions of water react with different compounds. For example hematitite reacts with water to from limonite.
3. **Carbonation:** Water reacts with water to form carbonic acid. Carbonic acid reacts with rock.
4. **Oxidation:** Rocks containing iron (Fe) undergo oxidation. It makes the rocks more porous and breakable.
5. **Solvent Action:** Water is universal solvent. It dissolves some of the mineral matter. Thus it causes chemical weathering.

(c) Biological weathering

The weakening and then disintegration of rock by plants, animals and microbes is called biological weathering.

1. **Plants:** Growing plant roots can exert stress or pressure on rock. This is physical process. But pressure is exerted by a biological process (growing roots). Biological processes can also produce chemical weathering. For example, plant roots or microorganisms produce organic acids. These acids dissolve minerals.

2. **Microbial activity:** Microbes alter the chemical composition of soil. It prepares the soil for weathering. One example of microbial activity is lichen. Lichen is symbiotic relationship between fungi and algae. Fungi release chemicals. These chemicals break down rock minerals. These minerals are consumed by the algae. This process continues. Thus holes and gaps are developed on the rock. It exposes the rock for further to physical and chemical weathering.
3. **Animals:** Burrowing animals can move rock fragments to the surface. It exposes the rock to more intense chemical, physical, and biological processes. These processes indirectly enhance the process of rock weathering.

(B) DERIVATION OF PARENT SOIL MATERIAL

Soil is classified into two types on the basis of parent material: residual plant material and transported parent material.

(a) Residual parent Material

Residual parent material is formed by the breakdown of rocks. Rock minerals are exposed to atmosphere at some places. The intensity of weathering is greatest at these places. Complete physical decomposition and chemical alteration take place at the surface of a residual parent material. The mineral particles become larger with the increase of the depth. Therefore, these particles are less altered chemically. They incorporate in the bed rocks. Residual parent material is composed of three types of rocks:

a) **Igneous rocks:** Igneous rocks are formed by the cooling of magma. Magma is hot mixture of elements. These rocks are present above or below surface of the earth.

b) **Sedimentary rocks:** Different materials are deposited in lakes and oceans. This material form layers. After passing a long geological time, rocks are formed. Such rocks are called sedimentary rocks.

c) **Metamorphic rocks:** These are formed of igneous rocks or sedimentary rocks. These rocks are heated to intense pressure at considerable depths within earth. Original minerals melt. It forms new minerals. As a result new rock is formed called metamorphic rock.

(b) Transported Parent Material

They are composed of derived mineral particles. Various agents bring these derived particles from their places of origin. The transported soils vary according to the transporting agent. Most of the agent operates one after the other. Therefore, the parent material of this class does not resemble the underlying rocks. The soil may be:

1. **Colluvial:** The soil transported by gravity or wind is known colluviall soil. This transported deposited material is called talus. Such soil is present mostly in mountainous regions. Hillside deposits are colluviall in nature. Colluvial parent material is coarse and stony. It has unfavorable physical and chemical characteristics. Therefore, it has least agricultural importance.
2. **Alluvial:** Soil transported by water is called alluvial soil. It has three general classes:
   - **Alluvial fans:** Streams leave a narrow valley in a mountainous area. It then

suddenly descends to a broader valley. Here minerals are deposited in the form of a fan. It is called alluvial fan. These are found in mountainous areas.

- **Floodplain:** It is composed of flood affected valley. Its soil is rich in nutrients. It is suitable for agriculture.
- **Delta deposits:** These are present near the mouth of rivers. The river water has a large amount of suspended material. This material settles in this land. Deltas are clayey in nature. Delta has fertile soil. It is excellent for agriculture.

3. **Glacial:** Soil transported by glaciers is glacial soil or **glacial till**. Glacier carries materials like boulders, gravel, sand and clay from one area. It deposits them in another area. It forms glacial till. It has two forms:
    - Material carried in the base of glacier and deposited under it is called **basal till.**
    - Material carried on or near the surface of glacier and deposited on melting of glacier is called **ablation till.**
4. **Aeolian (eolian or aeolian):** The soil transported by wind is called aeolian soil. Aeolian sediments consist primarily of sand or silt-sized particles. These materials are extremely well sorted. These are free of coarse fragments. Some rounding and frosting of mineral grains may be present in it. It has two forms: sand dunes and loess:
    - **Sand Dunes:** Sand dunes are found in dry regions. Weathering of sandstone and other rocks produce sand. It is blown and deposited as dunes. Sahara desert is example of sand dunes.
    - **Loess**: Loess is composed of windblown materials. It is primarily composed of silt. Some fine sand and clay particles are also present in it.

(C) SOIL ORGANIC MATERIAL (SOM)

Soil organic matter (SOM) is the organic matter component of soil. It consists of plant and animal residues, cells and tissues of soil organisms. It also includes substances synthesized by soil organisms. The weathered rock material forms fine earth. Organic matter is added to it. The lichens and higher plants die. Their dead parts get mixed up with rock material. The remains of minerals of plants and their waste products are also added to this mixture.

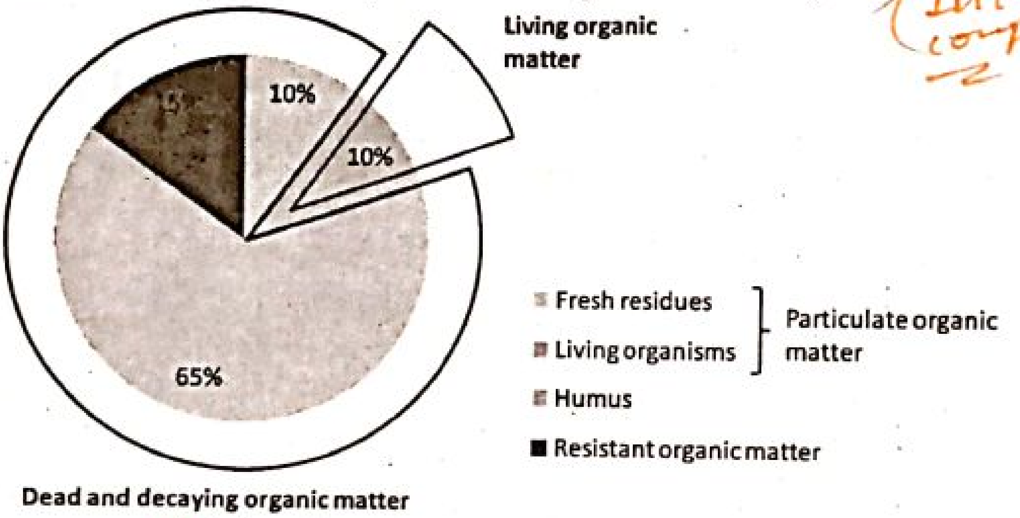
Composition: The concentration of SOM in soils ranges from 1% to 6% of the total topsoil. Some the upper horizons of some soils consist of less than 1% organic matter. Such soils are mostly limited to desert areas. The SOM content of soils in low-lying, wet areas can be as high as 90%. Soils containing 12-18% SOC is classified as organic soils.

Components: SOM can be divided into three general pools:

a) Living biomass of microorganisms
b) Fresh and partially decomposed residues
c) Humus: the well-decomposed organic material

Effect of SOM: SOM exerts many positive effects on soil physical and chemical properties. The presence of SOM is critical for soil function and soil quality. Its positive effects as follows:

1. SOM improves the soil structure.
2. It improves aggregation, water retention, soil biodiversity, absorption and retention of pollutants.
3. It has buffering capacity.
4. It cycles and store plant nutrients.
5. It increases soil fertility by providing cation exchange sites.
6. It acts as reserve of plant nutrients, especially nitrogen (N), phosphorus (P), and sulfur (S) and other micronutrients. These are slowly released upon SOM mineralization.
7. SOM also acts as a major sink and source of soil carbon (C). SOM contain almost 58% C. It is called soil organic carbon (SOC). Thus soil is one of the largest carbon sinks on the planet. It plays a major role in the global carbon cycle. (Int. comp)



(iii)

SOIL TEXTURE *(a)

Relative proportion of the soil particles size is known as soil texture. The process of weathering forms the texture of soil. Soil consists of fragments of various sizes. Their volume is 45-50% of the total soil. Soil texture causes variations in the soil water and soil air. Therefore, it indirectly affects the plants. The texture or mechanical composition of the soil determines the amount of water hold by it.

Sizes of soil particles

Majority of the soil particles consist of silica and silicates. They are relatively insoluble. Soil particles have following sizes:

1. Gravel: more than 2mm
2. Coarse Sand 2.0— 0.2 mm
3. Fine Sand 0.2— 0.02 mm
4. Silt 0.0—0.002 mm
5. Clay Less than 0.002 mm

Soil textural classes

Soil texture gives relative proportions of sand, silt, or clay in a soil. The **soil textural class** is a grouping of soils based upon these relative proportions.

a) **Clay:** Soils with the finest texture are called **clay** soils.
b) **Sands:** The soils with the coarsest texture are called **sands**.
c) **Loam:** The soil that has a relatively even mixture of sand, silt, and clay and exhibits the properties from each separate is called a **loam**. There are different types of loam.

We can determine the percentages of clay, silt, and sand in a soil. Now we can develop **textural triangle**. It will determine the texture class of a soil.

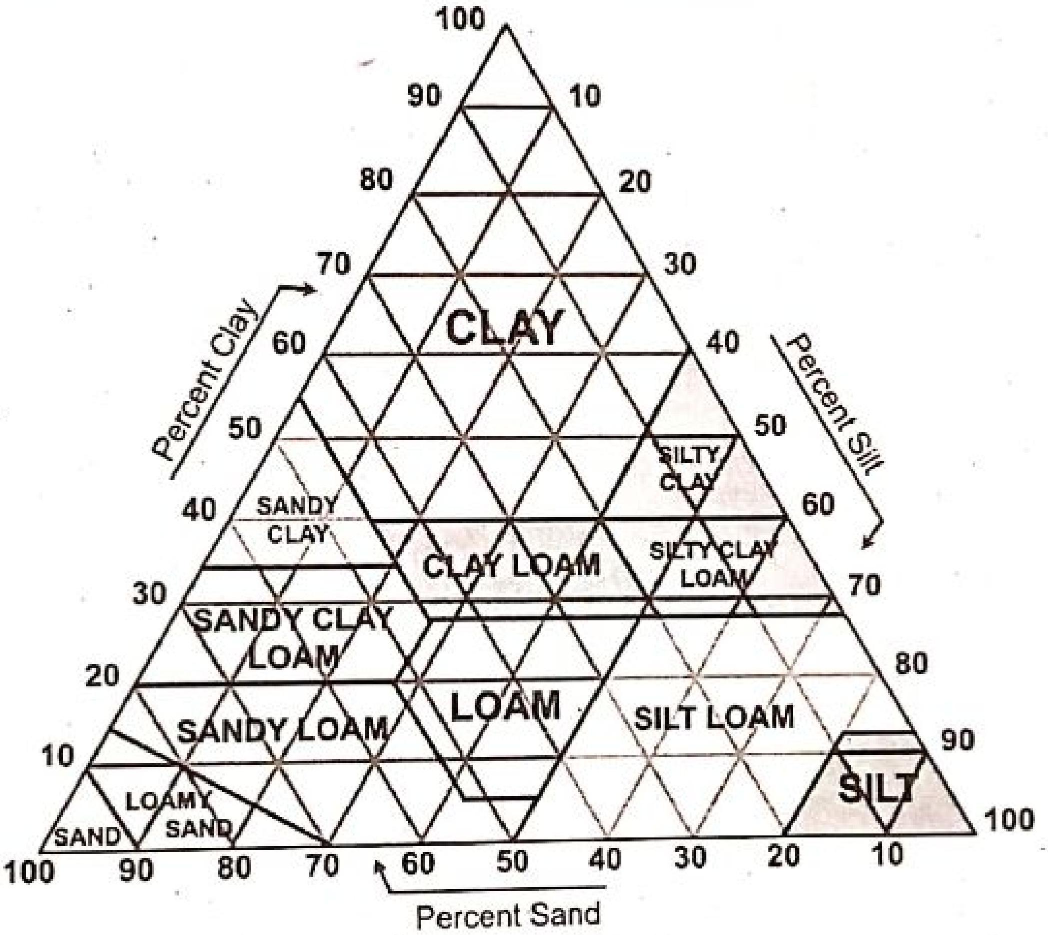


Fig: Textural triangle

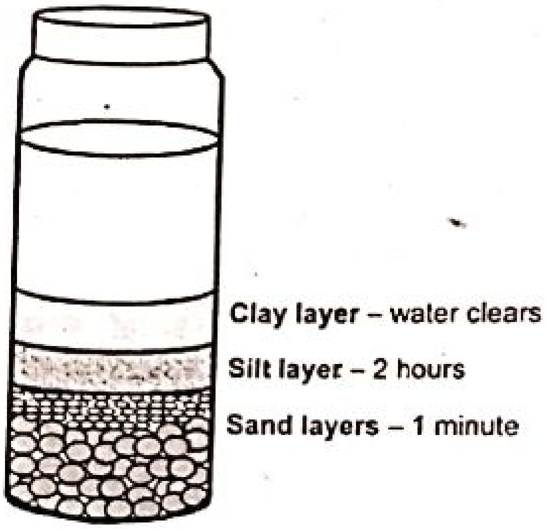
Soil particles are classified as gravel, sand, loam, silt and clay. Or it may be sandy loam, silt loam and sandy soils. The characteristics of the individual soil particles are as follows:

1. Gravel

It is composed of large mineral particles. These particles are formed by weathering of rocks. It is much coarse soil. Size of its particles is more than 2.00mm. It does not support much vegetation. [illegible]

2. Coarse Sand

The size of particles of coarse sand is 2.0— 0.2 mm. Thus it has large sand particles. The grains of coarse sand may be rounded or irregular in shape. These sand particles are loose and single grained. Sand particles are fragments of rocks. They also contain minerals like silica and quartz (SiO_2).They are insoluble in water and are chemically inert. Therefore, large pore spaces are present between them. It has good aeration. It is useful for the plants. But excessive drainage occurs in it. Thus it has lower water holding capacity. It causes deficiency of soil nutrients.



2. Fine Sand

The size of particles of fine sand particles is 0.2— 0.02 mm. It has smaller sized sand particles. Its properties are similar to coarse sand. But it has power of coherence (attachment). Fine sand only allow slow water movement. But it does not retain much water. It has small sand particles. Therefore, they retard free movement of water and air.

3. Silt

The size of particles of silt is 0.0—0.002 mm. Silt is composed of fragments of rock mineral. The small particles retard the movements of air and water. Silt also exhibits the properties of colloids. Silt has tendency to absorb and retain water.

4. Clay

The sizes of particles of clay are less than 0.002 mm. Clay differs from coarse sand, fine sand and silt both chemically and physically. Clay has small particles. So it is colloidal in nature like gelatine. It can absorb and retain a large amount of water. It has small quantity of electrolytes. Therefore, some of the clay particles aggregated together to form large sized particles known as **crumbs. This process of crumb formation of clay is called flocculation.** But certain minerals like sodium reverse this effect. It causes dispersion of crumbs. This process is known as **deflocculation.**

5. Loam

A soil in which the sand, silt and clay particles are present more or less in equal proportion is called loam. A loam soil with predominant clay particles is called clay loam. It has more classes. These are sandy, loamy sand, silt loam, silty sandy clay loam, silty clay and clay etc.

Importance of Soil Texture

Different types of soil particles are present in different soils. These particles contribute to the nature and properties of soil as a whole.

Importance of sandy soil

Sandy soil has following importance.

1. Texture has good effect on management and productivity of soil. Sandy soils are of open character. It is loose and friable.
2. Such type of the texture is easy to handle in tillage operations.
3. Sand facilitates drainage and aeration. It allows rapid evaporation and percolation.
4. Sandy soils have very little water holding capacity. Such soils cannot withstand drought. They are unsuitable for dry farming.
5. Sandy soils are poor store house of plant nutrients.
6. Sandy soil contains low organic matter.
7. Leaching of applied nutrients is very high in sandy soil.
8. In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.

Importance of clayey soil

1. Clay particles play a very important role in soil fertility.
2. Clayey soils are difficult to till. It requires much skill in handling. Moist clayey soils are much sticky. It becomes very hard on drying. Thus it becomes difficult to break it.
3. They have fine pores, and are poor in drainage and aeration.
4. They have a high water holding capacity and poor percolation. This may cause water logging.
5. They are generally very fertile soils for plant nutrient content. Rice, jute, sugarcane can be grown very successfully in these soils.

Importance of loamy soil

1. Loam and silt loam soils are highly desirable for cultivation.
2. The best agriculture soils contain 10 – 20 per cent clay and 5 – 10 per cent organic matter. The rest are equally shared by silt and sand.

SOIL STRUCTURE (b) ✓

The soil structure includes the aggregation of soil particles. Soil structure plays role in the determination of soil characteristics. Only coarse sand and fine sand are single grained. All other soil particles aggregate into larger structural units. The individual soil particles coalesce (sticking together) with the help of soil colloids. They form various sizes soil structures. The diameter of these particles is 1-10 mm. They have different shapes and forms. Formation of soil structure depends upon following factors:

1. **Parent material:** Parental material directly affects the soil structure. For example, high clay and adsorbed Na give a coarse pattern. But low clay and adsorbed Ca give finer-grained pattern. Similarly, soft sandstone has single grain or massive structure. But shale (soft sedimentary rock) has higher clay content. So they form prismatic or columnar structure.
2. **Flocculation:** The aggregation of individual particles into small clumps or clusters is

called flocculation.)

3. **Granulation:** The cementation of aggregates into masses is called granulation. Plant roots and root hairs grow. These break the soil mass or clods into granules.
4. **Humus formation:** Microbes act upon dead plants and animals and decay them. It forms humus. Humus acts as cementing force for granules.
5. **Accumulation of soil colloids:** These colloids hold different particle of soil and form different structures in soil.
6. **Activity of organisms:** The activity of microorganism protozoa and worms (particularly earthworms). The activities of these organisms break the large particles into smaller particles.
7. **Fluctuating temperatures:** It also affects the soil structure. Abrupt change in temperature may break the hard soil layers. It changes them in to particles of different structures.
8. **Liming and gypsum of the soil:** These also affect soil structure.

Importance of soil structure

1. Aggregation of the soil is essential for soil with fine texture. A structured soil has favourable features of both coarse and fine textured soils.
2. Aggregated soil is more favourable for plant growth.
3. Aggregation makes the soil permeable for water.
4. It helps in heat transfer.
5. It improves soil aeration and increases the water holding capacity of the soil.
6. The aggregated soils are not easily eroded by wind and water.

Types of structure of soil

The soil may be:

a) **Single-grained:** The soil particles exist as individuals as single grained. The do not form aggregates. These are found in C horizon.

b) **Masses:** The soil material aggregate to form small masses. These are also found in or C horizon.

c) **Aggregates:** Here primary particles group together. They form clusters of aggregates.

There are four types of structure of soil:

1. **Platy or plate like:** In this case, all the soil particles are arranged in a horizontal manner. They form small flat plate like structures. It is mostly present in virgin soils. These may also be found in subsurface of A horizon of forests and lower horizons.
2. **Prism like:** In this case, the soil particles are arranged in vertical aggregates. They are bounded by flat surfaces. Their lengths vary for different soils. Prism like soils is found in arid and semi-arid regions. It has two forms:
   a) **Columnar:** The prism like soils in which the top are rounded is called columnar.
   b) **Prismatic:** In this case the top is plane or level.
3. **Blocky or block like:** In this case soil aggregates are present in the form of blocks. Their three dimensions more or less equal. They have rounded or flat six faced structures. Blocky soils are common in heavy subsoil in humid regions. It has three

forms:

a) **Angular Blocky:** When the edges of the cubes are sharp with distinct rectangular faces, it is called angular blocky.
b) **Subangular Blocky:** When the sub-rounded aggregates are present the aggregates are called Subangular.

4. **Spheroidal:** In this case, the aggregates are rounded in outline. They are not more than half an inch in diameter. Spheroidal soil is present in furrows or slices. It undergoes many rapid changes. It has two forms:
   a) **Granular:** In this case, the spheroidal aggregates are non-porous
   b) **Crumb:** In this case the spheroidal soil is porous. Granular soil is the best soil for plant growth.

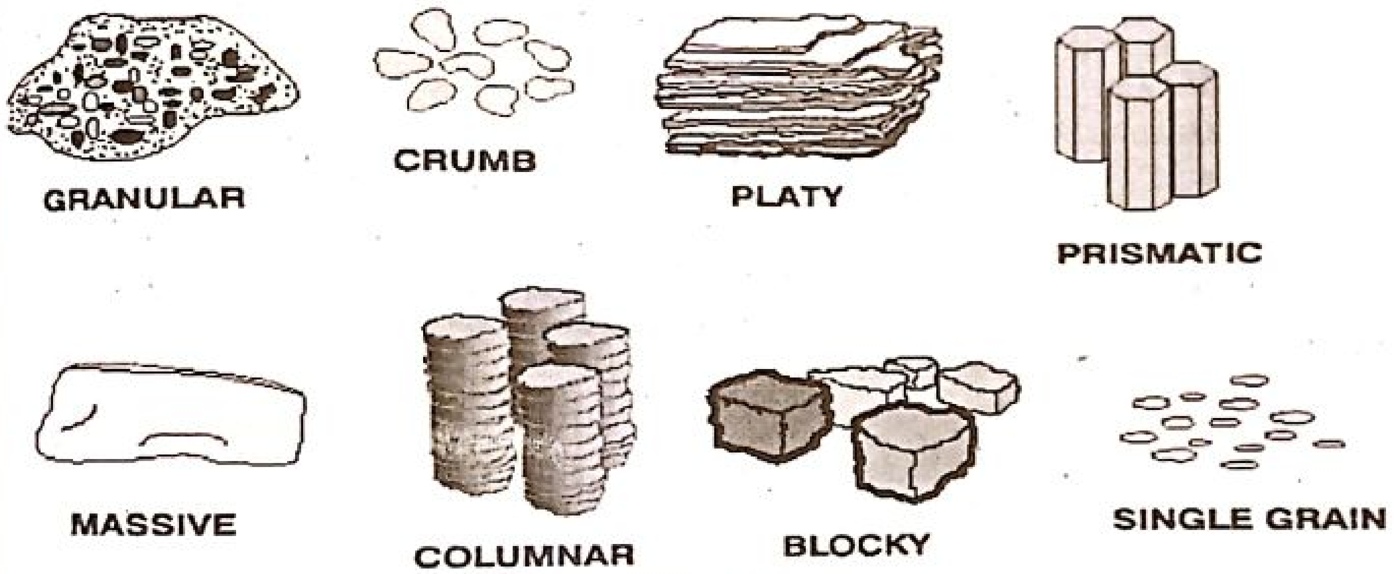


Fig: Different soil structures

SOIL PROFILE (Not included in B.Sc syllabus)

The arrangement of soil particles in layers is called soil profile. A soil horizon makes up a distinct layer of soil. The horizon runs roughly parallel to the soil surface. It has different properties and characteristics than the adjacent layers above and below. The **soil profile** is a vertical section of the soil that shows all of its horizons. The soil profile extends from the soil surface to the parent rock material.

The **regolith** includes all of the weathered material within the profile. The regolith has two components:

a) **Solum:** Solum includes upper horizons. It is the most weathered portion of the profile.
b) **Saprolite**: Saprolite is the least weathered portion. It lies directly above the solid, consolidated bedrock. But it is present beneath the regolith.

Master Horizons

There are **5 master horizons** in the soil profile. Not all soil profiles contain all 5 horizons. The soil profiles differ from one location to another. The 5 master horizons are represented by the letters: O, A, E, B, and C.

1. **horizon:** The O horizon is a surface horizon. It is composed of organic material at various stages of decomposition. It is most prominent in forested areas. Here there is the accumulation of debris fallen from trees.
2. **A horizon**: The A horizon is a surface horizon. But it largely consists of minerals (sand, silt, and clay) and with a large amount of organic matter. This horizon is predominantly the surface layer of many soils in grasslands and agricultural lands.
3. **E horizon**: The E horizon is a subsurface horizon. It is heavily leached. **Leaching is the process in which soluble nutrients are lost from soil due to precipitation or irrigation.** The horizon is typically light in color. It is generally found beneath the O horizon.
4. **B horizon:** The B horizon is a subsurface horizon. It has accumulated from the layers above. It is a site of deposition of certain minerals. These minerals have leached from the above layers.
5. **C horizon**: The C horizon is a subsurface horizon. It is the least weathered horizon. It is also known as saprolite. It is composed of unconsolidated, loose parent material.

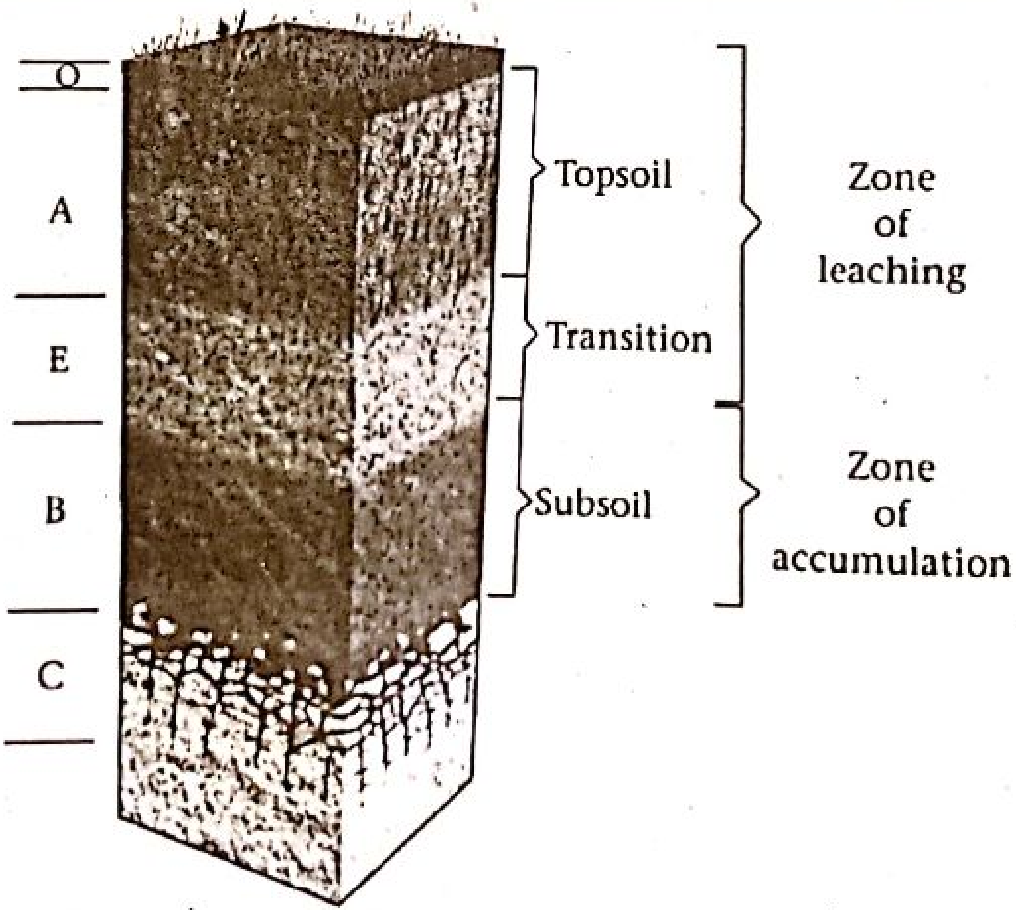
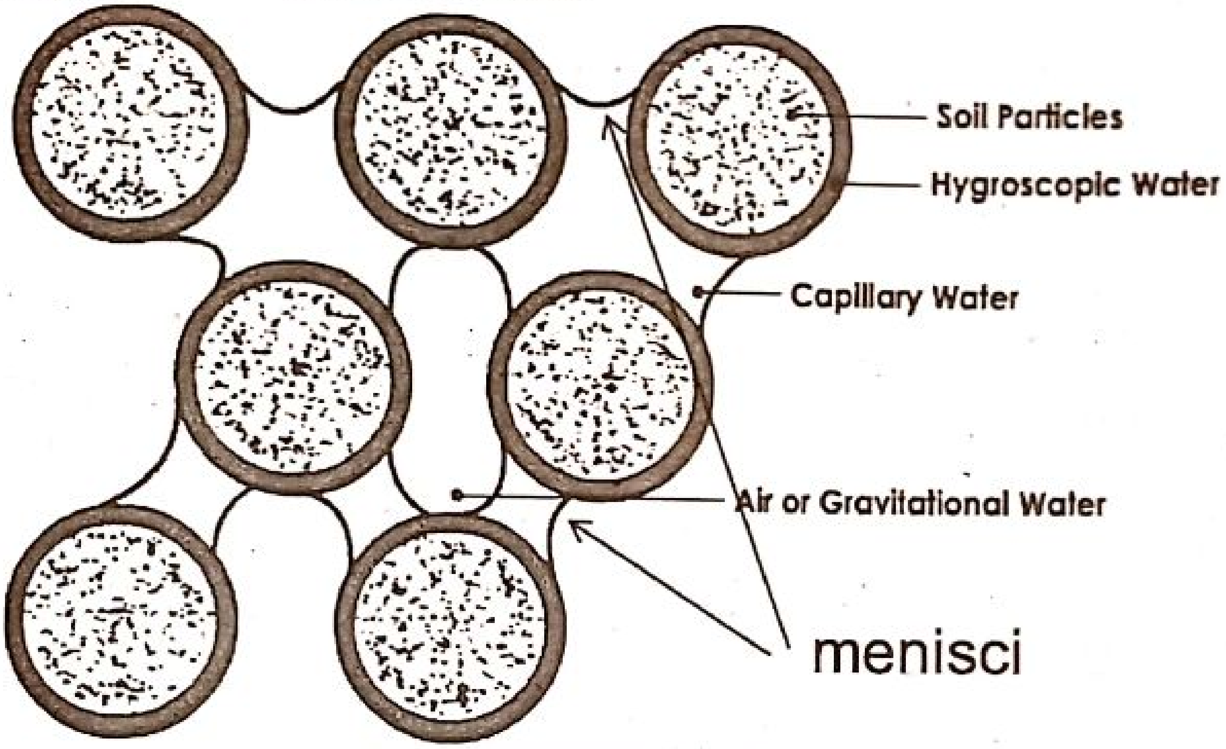


Fig: Soil profile

SOIL WATER

Soil is a great reservoir of water. The amount of water contained in this reservoir varies greatly in different soils and under different conditions. Its amount in ordinary garden soil is about 25 per cent by volume. The principal source of soil water is rain. There are following type of water present in the soil:



Three Main Types of Soil Water

1. **Run away water:** Some of the water drains away along the slopes after a heavy rainfall or irrigation. This is called run-away water. It is not available to the plant.
2. **Gravitational water:** Some of the water is absorbed by the soil and saturates its upper layers. It percolates downwards through the larger pores between the soils particles due to gravity. Finally it reaches the water table. This is called the gravitational water. Gravitational water is also not available to the plant.
3. **Soil holding water:** Much of the rainwater is retained by the soil particles. It makes the soil wet. The amount of water retained by soil after the removal of excess water by gravitation is called **the field capacity** or **the water holding capacity** of the soil.
4. **Hygroscopic water:** Water adsorbed on the surface of soil colloids is called hygroscopic water. It is tightly held by soil. It forms very thin films. It is not available to the plant.
5. **Capillary water:** The water which fills the spaces between the non colloidal smaller soil particles is called capillary water. It has the greatest importance for the plant. This water is available to plant. The plant absorbs this water through roots.
6. **Chemically combined water:** A small amount of water is bound to the molecules of some soil minerals by strong chemical bonds. It is also not available to the root. This is called chemically combined water.
7. **Water table:** The water level at some depth from the soil where all pore spaces are filled with water is called water table. It may be present from few feet to several hundred feet. Water rises from water table by capillary action. It is used by the plants.

Water availability for plants

1. **Maximum water holding capacity:** The moisture held by a saturated soil is called

maximum water holding capacity. In this case, the pore spaces in the soil are filled with water. It varies from the coarse texture to fine textured soil.

$$\text{Maximum water holding capacity} = \frac{\textit{weigt of saturated soil} - \textit{Weight of dried soil}}{\textit{Weight of oven dried soil}}$$

2. **Field capacity of the soil:** The hygroscopic and capillary water forms the field capacity of soil. It is different for different types of soils. Field capacity varies from 5 to 35%. The clay soil has the highest field capacity.

$$\text{Field capacity} = \frac{\textit{weigt of saturated soil} - \textit{Weight of oven dried soil}}{\textit{Weight of oven dried soil}} x100$$

3. **Wilting coefficient or permanent wilting point:** The amount of moisture left in the soil after a plant has permanently wilt is called wilting coefficient. Soil water is now empty for plant. More water must be added to the soil. Otherwise, the plant will die. The value of wilting coefficient depends upon the nature of the soil. It is lowest for the sandy soil. But it is highest for the clayey soil.

(iii)

CHEMICAL PROPERTIES OF SOIL

Chemically soil is composed of two parts: mineral matters and organic matters.

(A) Mineral Matter

Soil contains mixture of various minerals. About 20 minerals form almost 99% of the earth crust. Minerals are classified as:

(i) Primary Minerals, (ii) Secondary Minerals.

(i) Primary Minerals

They are reduced particles of the rock. No chemical change has occurred in these minerals. They are also called original minerals. The Important primary minerals are: Quartz, Feldspars, Mica, Amphibole, Pyroxene and Olivine.

1. **Quartz:** It is the common form of silica or SiO_2. It has hexagonal crystals. It is hard and is not affected by most of the weathering agencies. Is found in all the rocks.
2. **Feldspar:** These minerals form almost half of the rocks of the crust of the earth. These contain SiO_2, Al and either K or Na or Ca. The feldspars undergo hydration and hydrolysis with water. Therefore, it undergoes weathering.
3. **Mica:** It is composed of silicates (Si_2O_3) containing Al and one or more of K, Mg. Fe. H. Those varieties of mica which contain Fe are called **biotite or black mica**. Those without 'Fe' are called **Muscovite or white mica**.
4. **Amphibole (Hornblende):** It is a silicate (Si_2O_3) of Mg, Fe and Ca. Its most varieties are black in colour and produce rust coloured soil. It decomposes readily.
5. **Pyroxene:** It has hard crystals. They are green or dark coloured.
6. **Olivine**: It is composed of silicates of Fe and Mg. It is glassy and olive green yellow. It is unstable and decomposes easily.

(ii) Secondary Minerals

They are the products of decomposition of primary minerals. They are mostly present in fine materials especially in clays. The important secondary minerals are: carbonates, phosphates, sulphate, oxides and silicates

(B) Organic compounds

Organic matter is made up of partially decomposed remains of plant and animal tissues and the bodies of living soil microorganisms and the plant roots. The microorganism produces organic matter during decomposition. This organic matter binds the soil matter like glue. Soil becomes more granular due to such substances. Organic matter is important for soil fertility. It is rich in mineral nutrients. Thus it improves the soil conditions.

Soil organic matter has colloidal properties. Therefore, it increases the absorptive properties of soil. The organic matter content of the soil is very small in the soils of Pakistan in the plains contain 0.4 to 1.5 % organic matter. Soil has two types on the basis of organic matter.

- **Organic soil:** Soils containing more than 20% organic matter are called organic soils.
- **Mineral soil:** The soil containing less than 20% organic matter is called mineral soil.

BIOLOGICAL COMPONENTS (iv)*

The biological component of soil is composed of soil organism and soil organic matter.

SOIL ORGANISMS (a) *

Soil organisms included any organism inhabiting the soil during part or all of its life. Soil organisms have different sizes. Their sizes range from microscopic cells to small mammals. Microscopic organisms digest decaying organic material. Large animals live primarily on other soil organisms. Soil organisms play an important role in maintaining fertility, structure, drainage, and aeration of soil. They also break down plant and animal tissues. Thus they released stored nutrients. They convert these minerals into forms usable by plants. Some soil organisms are pests. Some of pests of crops are nematodes, slugs and snails, symphylids, beetle larvae, fly larvae, caterpillars, and root aphids. Some soil organisms cause rots. Some soil organisms release substances that inhibit plant growth. Some others are hosts for organisms that cause animal diseases.

Most of the functions of soil organisms are beneficial. Thus large numbers of organisms make the land fertile. One square metre of rich soil can have as many as 1,000,000,000 organisms.

Classification of soil organisms

Soil organisms are commonly divided into five groups according to size.

1. **Prokaryotes and Protists:** They are the smallest soil organisms. They include bacteria, actinomycetes, and algae. Most of the bacteria and actinomycetes are decomposer. They release their enzyme outside the body. These enzymes digest the decay matter into simple compounds. They absorb these compounds. Thus they recycle the nutrients. Some blue green algae and bacteria are involved in the nitrogen fixation. Algae are mostly photosynthetic.
2. **Microfauna:** This is next group of soil organism. These are less than 100 microns in length. They generally feed upon other microorganisms. The microfauna include

single-celled protozoans, some smaller flatworms, nematodes, rotifers, and tardigrades (eight-legged invertebrates).

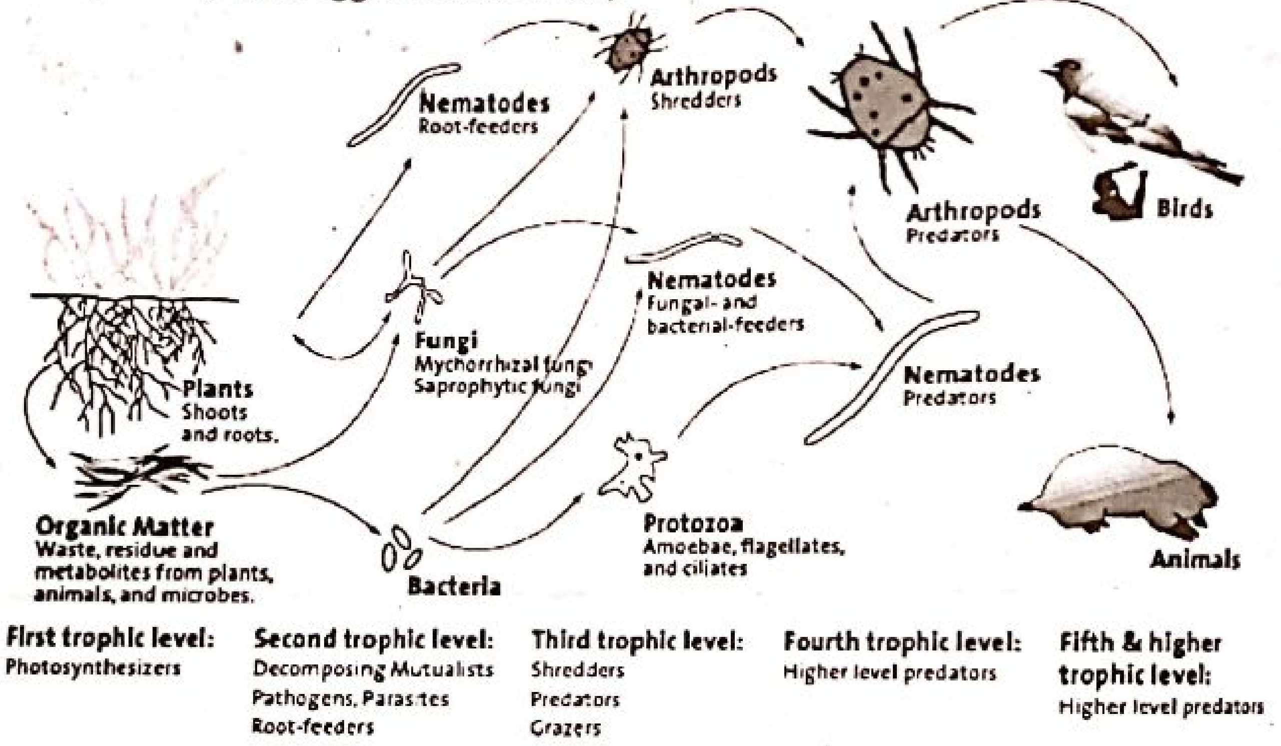


Fig: Soil organisms

3. **Mesofauna:** They are larger and are heterogeneous group. They include organisms that feed on microorganisms, decaying matter and living plants. They includes nematodes, mites, springtails (wingless insects), insect like proturans (feed on fungi) and pauropods.
4. **Macrofauna:** It is the fourth group of soil organisms. They are also quite diverse. The most common example is the potworm. It is white segmented worm. It feeds on fungi, bacteria, and decaying plant material. This group also includes slugs, snails, and millipedes. They feed on plants. They also include centipedes, beetles and their larvae, and the larvae of flies. They feed on other organisms or on decaying matter.
5. **Megafauna:** It constitutes the largest soil organisms. They include the largest earthworms. Earthworms are the most important organisms living in the topsoil. Earthworms pass both soil and organic matter through their guts. It performs following process.

- Aerating the soil
- Breaking up the litter of organic material on its surface
- Moving material vertically from the surface to the subsoil.

These processes are extremely important to soil fertility. They develop the structure of the soil as a matrix for plants and other organisms. It is estimated that earthworms completely turn over the equivalent of all the soil on the planet to a depth one inch (2.5 cm) every 10 years.

Some vertebrates are also found in the megafauna category. These include all sorts of burrowing animals like snakes,. lizards, gophers, badgers, rabbits, hares, mice, and moles.

Importance or role of soil organisms

Soil organisms play an important role in improving soil structure, aggregate stability, soil fertility and weathering of the soil. They affect whole of the soil environment. Thus they indirectly affect the plant growth. There are following functions of soil organisms:

1. **Decomposition:** It is one of the most important roles of soil organisms. Soil microorganisms like bacteria and fungi are responsible for decay of organic matter. Thus the elements are changed into the simple forms. Now they are again available to the higher plants.
2. **Role in natural cycles:** These soil organisms act as catalysts in a number of natural cycles. Some important are carbon, nitrogen, and sulfur cycles. The carbon cycle begins in plants. Plants combine carbon dioxide from the atmosphere with water. It makes plant tissues such as leaves, stems, and fruits. Animals eat the plants. They convert the tissues into animal tissues. The cycle is completed when the animals die. Their decaying tissues are eaten by soil organisms. It is a process that releases carbon dioxide.

   Proteins are basic organic tissues. Nitrogen is an essential element of all proteins. Presence of nitrogen determines the fertility of soil. Thus soil organisms play important role in nitrogen cycle. The plant or animal dies. Soil organisms break up the complex proteins, polypeptides, and nucleic acids in their bodies. They produce ammonium, ions, nitrates, and nitrites. The plants absorb them to build their body tissues.
3. **Biological nitrogen fixation:** Several groups of bacteria like *Azotobacter*, *Clostridium* live in aerated and unaerated soils. *Rhizobium* lives in leguminous roots. A number of blue-green algae also live in soil. They fix atmospheric nitrogen. This nitrogen enters into organic substances. Thus nitrogen once again enters the organic cycle. Nitrogen fixing organisms of soil increase the soil fertility.
4. **Weathering of soil:** The larger soil organisms (insects, worms, rodents etc.) cause mixing and weathering of soil. The movement of these organisms changes physical characteristics of the soil. Earthworms bring tons of underground soil above surface of the earth. Their movement in the soil improves soil aeration. The burrowing habits of rodents (rabbits, hares, mice, porcupine, hedgehog etc.) bring great amount of soil on the surface.
5. **Soil formation:** Plant roots penetrate the rock crevices. It widens the gap of cervices. It breaks the rocks apart. Therefore, plants roots play a great role in soil -formation.
6. **Formation of humus:** Soil organisms play a vital role in the formation of humus. Humus is a finely separated complex of organic materials composed of decaying leaves and other vegetable matter. Leaves fall from tree. They cannot be eaten by most animals. Fungi and other microflora attack on it. They make it soft and pliable.

It is called **litter.** Litter is eaten by variety of invertebrates. They fragment it into a **mulch**. These are consumed by different organism. Finally humus becomes fertilizer for plants.

SOIL ORGANIC MATERIAL (SOM) (b) * ✓

Soil organic matter (SOM) is the organic matter component of soil. It consists of plant and animal residues, cells and tissues of soil organisms. It also includes substances synthesized by soil organisms. The weathered rock material forms fine earth. Organic matter is added to it. The lichens and higher plants die. Their dead parts get mixed up with rock material. The remains of minerals of plants and their waste products are also added to this mixture.

Composition

Organic matter is the most important constituents of the soil. Organic matter is always present in the soil. But its amount is different in different soils. It varies from a mere trace to 100%. The soil containing 100% organic matter is known as **peat.** Some the upper horizons of some soils consist of less than 1% organic matter. Such soils are mostly limited to desert areas. The SOM content of soils in low-lying, wet areas can be as high as 90%. Soils containing 12-18% SOC is classified as **organic soils.**

Components

SOM can be divided into three general pools:

a) Living biomass of microorganisms
b) Fresh and partially decomposed residues
c) Humus: the well-decomposed organic material

Effect of SOM

SOM exerts many positive effects on soil physical and chemical properties. The presence of SOM is critical for soil function and soil quality. Its positive effects as follows:

1. SOM improves the soil structure.
2. It improves aggregation, water retention, soil biodiversity, absorption and retention of pollutants.
3. It has buffering capacity.
4. It cycles and store plant nutrients.
5. It increases soil fertility by providing cation exchange sites
6. It acts as reserve of plant nutrients, especially nitrogen (N), phosphorus (P). and sulfur (S) and other micronutrients. These are slowly released upon SOM mineralization.
7. SOM also acts as a major sink and source of soil carbon (C). SOM contain almost 58% C. It is called soil organic carbon (SOC). Thus soil is one of the largest carbon sinks on the planet. It plays a major role in the global carbon cycle.

Humus and Humification

The organic matter is present in the form of humus. **The dark coloured amorphous substance formed by the partial decay of dead animals and plants is called humus.**

The process of humus formation is called humification. Organisms decompose its components. Thus components are changed and used by plants.

Process of humification

There are following stages of humification:

1. Decomposition

The microorganisms like Bacteria, fungi, and protozoa attack on dead plant remains. They decay these matters. They ultimately decompose them into more or less simple salts. These salts contain Nitrogen and Phosphorus. Carbon dioxide and water are released. Earthworms drag down and partly digesting dead plant materials. Thus they also play some role in the break down organic matter. There are following stages of decomposition:

(a) **Litter:** The material formed by recently fallen leaves is called litter.

(b) **Duff:** It is present below the layer of litter. It is derived from litter. Process of decomposition is started in this layer.

(c) **Leaf mold:** This layer is present below the duff. The decomposition is completed in this layer.

2. Humus formation

This decomposed material is called raw humus or **mor**. Finally raw humus is mixed with minerals. It is changed into dark coloured amorphous and inert substance known as humus.

The rate of humification depends upon climatic and other conditions. It is most active at temperature between 35-40°C and under conditions of good soil aeration, moderate soil moisture and presence of calcium carbonate in the soil. Humus is light in weight. Thus it does not easily mix with other soil components.

Humus is formed as a result of many steps. These steps occur in the decomposition of organic matter. Humic substances have complex structure of. Therefore, humus cannot be used by many micro-organisms as an energy source. It remains in the soil for a relatively long time.

Composition of humus

Humus ranges in colour from brown to black. It consists of about 60 percent carbon, 6 percent nitrogen, and smaller amounts of phosphorus and sulfur. Humus is composed of two groups of substances: humic group and non-humic group.

(A) Humic group

Humic group is composed of complex materials. They are resistant to microbial attack. They make up about 60-80% of the soil organic matter. These have aromatic and have ring-type structures like polyphenols and polyquinones. Humic substances are amorphous. They have dark in colour. They have very high molecular weight. The humic substances are classified on the basis of solubility and resistance to degradation. These substances are humic acids, fulvic acids, hymatomelanic acids and humins.

a) **Fulvic acids:** It is soluble in water under all pH conditions. Their colour is commonly light yellow to yellow-brown.

b) **Humic acids:** It is soluble in water, except for more acid than pH 2. Common colours are dark brown to black.

c) **Humin:** It is not soluble in water at any pH. Thus it cannot be extracted with a strong base like sodium hydroxide (NaOH). It is commonly black in colour.

Fulvic and humic acids are complex mixtures of large molecules. Humic acids are larger than fulvic acids. Different substances are differentiated from each other on the basis of their water solubility.

Fulvic acids are produced in the earlier stages of humus formation. The relative amounts of humic and fulvic acids in soils vary with soil type. The humus of forest soils is characterized by a high content of fulvic acids. But the humus of agricultural and grassland areas contains more humic acids.

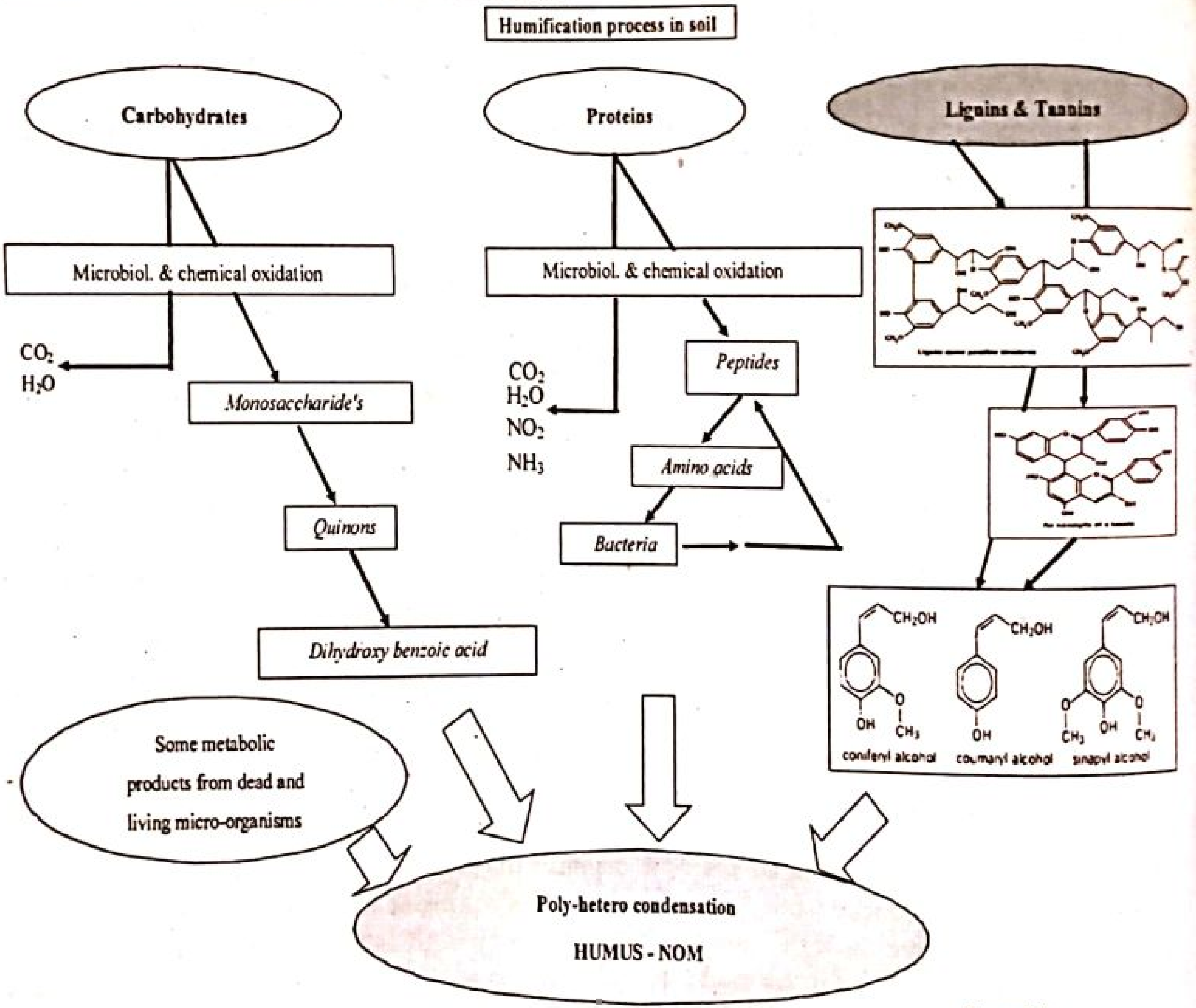


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Fig: Process of humification

(B) Non-Humic Group

Non-humic group forms about 20-30% of humus. These substances are less complex. They are less resistant to microbial attacks. These are composed of specific organic compounds. These compounds have definite physical and chemical properties. Some non-humic substances are synthesized. The other substances are modified by the action of microorganisms. Non-humic group is composed of following substances.

a) **Polysaccharides:** These are polymers of carbohydrates. They have sugar-like structure. They increase the stability of soil aggregates.

b) **Polyuronoides:** Soil microbes synthesized these compounds. These are present in the bodies of these microbes. After the death of these microbes, they interact with other organic material in the soil.

c) **Other simple Compounds:** Other simple organic compounds are also present in humus. These include organic acids and protein-like materials.

Classification of humus

Humus is classified into mor, mull, or moder. This classification is based on:

- Degree of its incorporation into the mineral soil.
- Types of organisms involved in its decomposition,
- Vegetation from which it is derived.

1. Mor-humus

A mor-humus formation is raw humus. It occurs in soil that has few micro- organisms or animals like earthworms. They decompose the organic matter that lies on the soil surface. Below this surface-litter layer is a distinct. It is strongly compacted humus layer. A layer of mineral soil underlies the humus. Fungi and small arthropods are the most common organisms in mor humus. Mor soils are usually acidic (low pH). These are characteristic soil of coniferous forest in cold regions and at high altitudes.

2. Mull-humus

A mull-humus formation is characteristic of hardwood forests, deciduous forests, or grasslands in warm, humid climates. It is porous and crumbly humus. It rapidly decomposes and becomes well mixed into the mineral soil. Thus distinct layers are not apparent in it. Bacteria, earthworms, and large insects are abundant in it. It pH is higher (alkaline).

3. Moder-humus

A moder-humus formation is intermediate between mor and mull. There is presence of many arthropod fecal pellets in moder. Therefore, it is also known as **insect mull**. Chains of these pellets bind plant debris and mineral particles together. It forms a netlike structure. A moder formation contains more organic material than a mull formation. But this material is not well mixed with mineral components.

Importance of Humus

Humus has following physiological functions:

1. It improves the physiological conditions of the soil.

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2. It improves both clay and light sandy soils. It makes the clay soil light. It increases the water holding capacity of the sandy soil.
3. It improves the soil air for the roots.
4. It acts as weak cement. It binds sand and clay particles in the form of tiny balls called **aggregates**. These aggregates make the soil compact.
5. Humus forms packing in a solid masse of rocks.
6. Humus separates the clay particles and makes the soil porous. This increases aeration, percolation and absorption of water. Roots easily penetrate into such a soil and bacterial activity increases.
7. Humus is a reservoir of nutrients and oxygen. They are necessary for the plant growth.
8. Humus improves fertilizer efficiency.
9. It improves the nutrients uptake like P and Ca.
10. Humus helps in salinity management. It protects plants from excess sodium.
11. It acts as buffer and maintains pH of the soil.
12. Organic humates are catalysts for increasing soil carbon levels.

(c) WATER

WATER

Water is a most important environmental factor. It is essential for all life processes. The living cells have about 80% water. It is essential for the maintenance of turgidity of cells. It acts as solvent for the exchanges of gases. All physiological processes like photosynthesis, transpiration and respiration require water.

Water covers about 73% of the surface of the earth. It is present in ponds, lakes, streams and oceans. Only 1% water is present in fresh water bodies like ponds, river, lakes etc. 99% water is present in oceans. It falls from the atmosphere in form of precipitation and water vapours.

PRECIPITATION

Precipitation includes rain, ① **snow,** ② **hail** ③ **and dew** ④ Precipitation occurs due to condensation of water vapours present in the air. Air or wind carries these vapours from oceans. Precipitation may be in the form of rainfall, snow fall or hailing.

1. Rain

The geography of the region and weather system determines the amount of rain fall. The air is saturated with water over oceans. It blows off the ocean. The air moves upward. There is low temperature there. The water vapours condense to form droplets. Thus clouds are formed. When the diameter of the droplets becomes 1mm, the rain starts falling.

Raining occur towards the ocean facing slopes. The other sides of the slopes are called **rain shadow**. They receive no raining. Therefore, they become deserts. Thus deserts are found behind high mountain ranges or near the coastal areas.

Distribution of rain fall over the year is an important limiting factor for the organisms. Rainfall is unevenly distributed over the year in the tropics and subtropics. They have well-defined wet and dry seasons. But rain fall is evenly distributed over the year in the temperate regions.

Different biomes are mainly defined by amount of rain fall:

Amount of rain fall /year	Kind of biome
0 – 10 inches	Desert
10 – 30 inches	Grass lands, savanna
30 – 50 inches	Dry forests
More than 50 inches	Wet forests

2. Snow

Snow is also a kind of precipitation. Snow fall mostly occur on high mountains. There is a freezing temperature on the high mountains. Therefore, water vapours are frozen to form snow. Generally, ten inches of snow is equal to one inch of rain. Snow deposits on the mountains and form glaciers. These glaciers have great importance for the hydrological cycle. They act as water reserve for whole of the year. Snow melts in the oceans. Its water drives the rivers throughout the year. Our irrigation system depends on these rivers. Snow may be harmful for plants. Its weight breaks off the tree branches. It can kill the saplings. Deep snow stunted the growth of plants.

3. Hail = (اولے)

Some of the drops of rain solidified due to very low temperature (below 0°C). They form hail stones. They fall on the surface of earth. Hail is not beneficial for the plants. It destroys different part of the plants. It destroys the seedling of the plants.

4. Dew

Water vapours of air condense when it comes in contact with cold surface. The moisture condenses on the surface in the form small droplets of water. These droplets are called **dew**. Sometimes, the temperature of surface is below freezing point. Therefore, the dew drops freeze. Such frozen dews are called **frost**. It occurs in temperate regions. Dew adds water content to the soil. It also increases humidity.

Dew has little effect on most of vegetations. But it has great effect in deserts. There is night cooling in the deserts. It causes heavy dew formation. This dew is important for plant life.

Importance of precipitation

1. Rain is a major source of soil moister for the plants.
2. Rain increases the humidity of air. Thus it reduces the rate of transpiration in plants. It affects many physiological functions of the plant.
3. The amount of rain determines the different vegetation zones. The deserts, grass lands and forest are formed due to different amount of rain.
4. Snow is important for driving rivers.
5. Snow may cause ice crystal formation in plant cells. It kills the plants.

6. Hail storm destroy the standing crops.
7. Dew has great significance for desert plants.

Distribution of vegetation in relation to moisture

Plants are distributed in nature according to amount of moisture available to them. Plants are divided into four groups in relation to moisture. These groups are hydrophytes, amphibiophytes, Mesophytes and xerophytes.

1. Hydrophytes

The plants grow in water reservoirs like ponds, lakes streams or rivers are called hydrophytes. These plants live in habits with abundance of water. They may be submerged hydrophytes, free floating hydrophytes, fixed floating hydrophytes.

(a) **Submerged hydrophytes:** These plants are fully submerged in water. They may be rootless. Their stem is soft and tender. Cuticle is absent in them. Vascular tissues are poorly developed. Mesophyll of the leave is not differentiated into palisade and spongy. They have special type of stomata called **hydathodes**. Its example is Hydrilla.

(b) **Free floating plants:** They are not anchored in the soil. Roots are absent in them. Hydathodes are present only on the dorsal surface. Its examples are wolffia, Pistia.

(c) **Fixed floating plants:** They are anchored in the soil and their leaves are free floating on the surface of water. They occur in shallow water. They have well developed roots. The stem is present in the form of rhizome. Its example is Marsilea.

2. Amphibiophytes

The moisture loving plants are amphibiophytes. They grow on very moist and swampy places. These places are present on the sides of ponds, lakes and rivers. Their roots and part of stem are embedded in the mud. Most of their characteristics are intermediate between hydrophytes and mesophytes. They have well developed mechanical and conducting tissues. Their endodermis is thick walled. They have system of air space in the body. Their example is sagittaria.

3. Mesophytes

The land plants which grow in places which are neither dry nor wet are called mesophytes. They are intermediate between hydrophytes and mesophytes. Many of the cultivated, ornamental and evergreen plants belong to this group. They have well developed tap root and adventitious roots. The stem is erect. The leaves are large with waxy coating. Stomata are present on the lower surface of the leaves. The leaves are dark green in colour. They readily wilt even in slight water deficiency.

4. Xerophytes

The desert plants are called xerophytes. They face the extreme shortage of water. They have following adaptation to reduce the rate of transpiration.

(i). Many xerophytes posses small, thick leaves. It reduces the surface are proportional to volume of the plants. Thus it reduces the loss of water by transpiration.

(ii). They have thick, waxy and leathery cuticle.

(iii). The stomata are on the lower surface of the leaves. These stomata are present in depressions.

(iv). Some plants like cacti shed their leaves during the dry seasons. Therefore, the transpiration is stopped completely. They have stem as their photosynthetic organ. Their stem store water in the rainy season and use it in dry condition.

(v). Most of their body is composed of water storing cells. Such plants are called **succulents.**

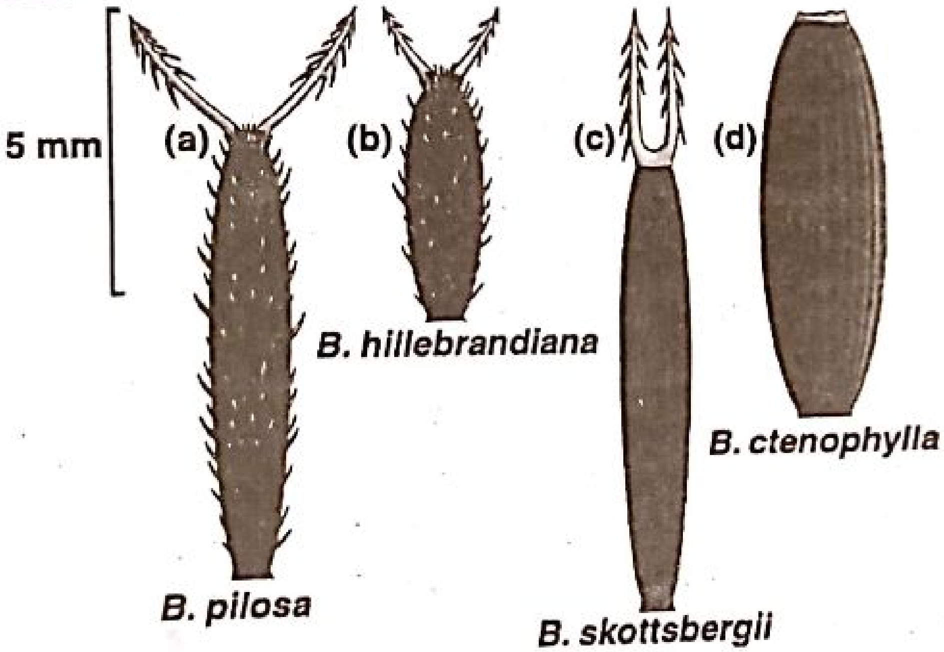

Fig: Some Xerophytes

(D) WIND

WIND

Air in motion is called wind. It can circulate gases, water vapours and small soil particles. The action of wind is an ecological factor. Wind is caused by differences in the atmospheric pressure. When a difference in atmospheric pressure exists, air moves from the higher to the lower pressure area. It causes winds of various speeds.

Ecological importance of wind

Wind affect may be direct or indirect. The direct effects of wind are seen in regions with continuous action of high wind velocities. There are following affect of wind:

(A) Direct effects of wind

It has following direct effects:

1. **Uprooting plants:** Plants may be uprooted and blown away by storm winds in coastal regions or exposed mountain tops. Therefore, the vegetation of these areas is largely composed of species with prostrate or stunted growth. They have well developed underground roots or rhizome system.

2. **Deformation of plants:** There is a continuous and unidirectional wind pressure in coastal regions. Therefore, the trees and their branches direct themselves towards the lowered side. Continuous wind alters the position of shoot permanently. Trees trunks become inclined on ridges. This called deformation.
3. **Breaking of plant parts:** The branches of large trees are broken or entire trees are uprooted in strong winds or hurricane. The soft parts of the trees are broken. Some herbaceous plant become lay down on land. Plants like banana fallen on the ground. Wind blow away leaves and other lighter parts of the plants. It reduces the overall photosynthetic capacity of plants.
4. **Falling of flowers and fruits:** It is a big loss caused by wind. Heavy wind throws away flowers and fruits of the trees. In Pakistan, it heavily affects mango trees. A great amount mango flowers and fruits are fallen away each year due to wind. It causes huge losses to farmer.
5. **Dwarfing of plant:** During growth, plants cells divide by mitosis. Then elongation of cells starts. Large vacuoles are produced in the cells. It gives turgidity to plant cells. This turgidity in one direction elongates the cells. Thus plant grows upright. Some plants develop under the influence of winds. They cannot attain turgidity. Thus plant cannot grow upright. Therefore, plants remain dwarf.
6. **Lodging:** Violent winds cause flattening of the herbaceous plants to the ground. It is called **lodging**. It takes place in herbaceous and weak stemmed plants like grasses, maize, wheat, corn, sugar-cane etc.
7. **Abrasive action of particles:** Strong wind also carries sand particles. These particles have abrasive action on the leaves and tender branches. Crops grown near sandy tracts suffer from abrasive action of the wind.
8. **Desiccation:** Wind causes evaporation rapidly. It causes desiccation in plants. Dry leaves are very dangerous for plants. They can causes wilting of plants. Desiccation can kill leaves and fruits of the plants.

(B) Indirect effects of wind

Indirect effects of wind are physiological. These are:

1. **Transpiration:** Wind influences the rate of transpiration of plants. Air currents take away the air saturated with water vapour. It increases the transpiration. Wind velocity increases with height above the surface of the soil. Therefore, large plants are more affected by high rates of transpiration than the smaller ones.
2. **Cooling:** The epidermis of different parts of plants accumulates heat. Wind dissipates this heat rapidly. Thus wind causes cooling effects in plants. Similarly, continuous transpiration also causes cooling effect in plants. Wind increases transpiration.
3. **Stunted growth:** Strong winds increase transpiration rapidly. The plants cannot maintain an internal water balance. Therefore, these plants suffer from dehydration. They losses turgidity. Therefore, their organs become dwarfed. This is common in trees on sea coast, arctic, or alpine timberline.

4. **Soil erosion:** Wind carry out soil particles. It causes erosion of soil. Wind blow away top soil. Top soil has many mineral. Thus a large amount of minerals are lost due to wind.
5. **Dispersal of pollen grain for pollination:** Wind is also important for dispersal of pollen grains, seeds and fruits. Most of the plants depend on wind for pollination. This wind helps in cross pollination of different varieties of a species. Therefore, a large number of variations are produced in plants. It increases vigor in plants.
6. **Dispersal of seeds and fruits:** Plants need dispersal of their seed to far off places. So that competition among the plants may reduce. Wind disperses the seeds and fruits of plant to far off places. Their seed are grown in these areas. Thus wind helps in ecological succession and new varieties of plants are established in arid areas.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Heliophytes	The plants which grow best in full sunlight are called heliophytes.
Sciophytes	The plants which grow best at lower light intensities are called sciophytes.
Facultative Sciophytes	The plants which grow best in sun but can also grow fairly well under shade are called facultative sciophytes.
Facultative Heliophytes	The plants which although grow best at lower light intensities but can also grow well in full sunlight are called facultative heliophytes.
Soil	The weathered layer of the earth crust is called soil.
Edaphology	The study of soil is called Edaphology.
Colluviall soil	The soil transported by gravity or wind is known colluviall soil.
Aeolian	The soil transported by wind is called aeolian soil
Glacial	Soil transported by glaciers is glacial soil.
Alluvial	Soil transported by water is called alluvial soil.
Loam	A soil in which the sand, silt and clay particles are present more or less in equal proportion is called loam.
Soil structure	The soil structure includes the aggregation of soil particles.
Peat	The soil containing 100% organic matter is known as peat.
Litter	The material formed by recently fallen leaves is called litter.
Duff	It is present below the layer of litter. It is derived from litter. Process of decomposition is started in this layer.
Leaf mold	This layer is present below the duff. The decomposition is completed in this layer.
Humus	The dark coloured amorphous substance formed by the partial

	decay of dead animals and plants is called humus.
Humification	The process of humus formation is called humification.
Precipitation	Precipitation includes rain, snow, hail and dew.
Hydrophytes	The plants grow in water reservoirs like ponds, lakes streams or rivers are called hydrophytes.
Amphibiophyte	The moisture loving plants are amphibiophytes.
Mesophytes	The land plants which grow in places which are neither dry nor wet are called mesophytes.
Xerophytes	The desert plants are called xerophytes.

MODEL SUBJECTIVE QUESTIONS

1. **Discuss scope and development of ecology.**
2. **Write note on quality of light.**
3. **Give classification of plants on the basis of light.**
4. **Describe different ecophyiological responses of light.**
5. **Give temperature classification of plants.**
6. **Give ecophyiological role of temperature.**
7. **Describe process of soil formation.**
8. **Write note soil profile and soil structure.**
9. **Write note on soil water.**
10. **Write note on organic matter in soil.**
11. **Give classification of plants on the basis of moisture.**
12. **Write not on wind.**

SHORT QUESTIONS

1. What is visible spectrum? What colours are included in it?

Ans: The waves of visible spectrum bring most of the energy on the earth. It includes the wavelength between 400-750 millimicrons. Visible spectrum is divided into seven colours. These colours are red, orange, yellow, green, blue and violet.

2 What is Invisible spectrum? What are its two types?

Ans: It has two parts: The wavelengths below 400 are called ultraviolet rays. Most of these ultraviolet rays are filtered by the ozone layers. The wavelength above 750 millimicrons is called infra red rays. These waves pass most of heat to the earth.

3. Differentiate between heliophytes and sciophytes?

Ans: The plants which grow best in full sunlight are called heliophytes. The plants which grow best at lower light intensities are called sciophytes.

5. What are Facultative Sciophytes?

Ans: The plants which grow best in sun but can also grow fairly well under shade are called facultative sciophytes.

6. What are Facultative Heliophytes?

Ans: The plants which although grow best at lower light intensities but can also grow well in full sunlight are called facultative heliophytes.

7. What are ill effects of low temperature on plant?

Ans: Low temperature causes cold injuries. Water is frozen into ice crystals in the intercellular spaces. It causes injury to cells.

8. What are the effects of high temperature on plant?

Ans: Extremely high temperature cause adverse effects on a number of vital physiological processes like respiration, transpiration, protein metabolism etc. These effects cause stunting and finally death of plants. This is called as Heat Injury.

9. What are Hekiskotherm?

Ans: It includes plants of Arctic and Alpine regions (above 16000 teat in tropics and 12000 feet in temperate) with very low temperature. Alpine vegetation prevails in such locality.

10. How does temperature affect in the spreading of diseases?

Ans Temperature and humidity affects the spread of plant diseases. Low temperature along with high humidity favours the attack of rust, damping off, seedling blight, foot rot and root rot.

11. What is soil? Name its components.

Ans: **The weathered layer of the earth crust is called soil.** Typically soil is made up of parent material. Organic matter and living organisms incorporate into it. The spaces remaining between the solid particles are filled with water and gases.

12. What is chemical weathering?

Ans: Chemical process of weathering consists of hydrolysis, carbonation and hydration. It converts certain minerals into soluble derivatives. They are then dissolved away from the rocks.

13. What is soil texture? How is it formed?

Ans: **Relative proportion of the soil particles size is known as soil texture.** The process of weathering forms the texture of soil.

14. What is coarse sand? What are its disadvantages?

Ans: The size of particles of coarse sand is 2.0— 0.2 mm. Thus it has large sand particles. Large pore spaces are present between them. It has good aeration. It is useful for the plants. But excessive drainage occurs in it. It causes deficiency of soil nutrients.

15. What are flocculation and deflocculation?

Ans: This process of crumb formation of clay is called **flocculation.** But certain minerals like sodium reverse this effect. It causes dispersion of crumbs. This process is known as **deflocculation.**

16. What is loam?

Ans: **A soil in which the sand, silt and clay particles are present more or less in equal proportion is called loam.** A loam soil with predominant clay particles is called clay loam.

17. What is piety?

Ans: **Piety:** In this case, all the soil particles are arranged in a horizontal manner. They form small flat plate like structures. It is mostly present in virgin soils.

18. What is Run away water?

Ans: Some of the water drains away along the slopes after a heavy rainfall or irrigation. This is called run-away water. It is not available to the plant.

19. What is field capacity of soil?

Ans: The amount of water retained by soil after the removal of excess water by gravitation is called **the field capacity** or **the water holding capacity** of the soil.

20. What is hygroscopic water?

Ans: Water adsorbed on the surface of soil colloids is called hygroscopic water. It is tightly held by soil. It forms very thin films. It is non-available to the plant.

21. What is wilting coefficient or permanent wilting point?

Ans: The amount of moisture left in the soil after a plant has permanently wilt is called wilting coefficient.

22. Give two functions of humus.

Ans: It improves the physiological conditions of the soil. It improves both clay and light sandy soils. It makes the clay soil light. It increases the water holding capacity of the sandy soil.

23. What are humus and humification?

Ans: The dark coloured amorphous substance formed by the partial decay of dead animals and plants is called humus. The process of humus formation is called humification.

24. What is lodging? In which plants does it occur?

Ans: Violent winds cause flattening of the herbaceous plants to the ground. It is called **lodging**. It takes place in herbaceous and weak stemmed plants like grasses, maize, wheat, corn, sugar-cane etc.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. Which of the followings form visible spectrum?

(a) 400-750 (b) 300-600 (c) 200- 700 (d) 400- 500

2. The ultraviolet radiations have wavelengths less than:

(a) 300 (b)400 (c) 700 (d) 500

3. The infrared radiations are more than:

(a) 300 (b)400 (c) 750 (d) 500

4. The plants which grow best at lower light intensities are:

(a) Sciophytes (b) Heliphytes (c) Facultative sciophyte (d) none

5. The study of soil is called:

(a) Edaphology (b) Ecology (c) Synecology (d) Autecology

6. The parent material formed by the breakdown of rocks is:

(a) Residual (b) Colluviall (c) Aeolian (d) Alluvial

7. The soil transported by gravity or wind is:

(a) Residual (b) Colluviall (c) Aeolian (d) Alluvial

8. Soil transported by water is called:

(a) Residual (b) Colluviall (c) Aeolian (d) Alluvial

9. The soil with more than 2mm particles is:

(a) Gravel (b) Coarse Sand (c) Fine Sand (d) Silt

10. The soil of with particle size 0.0—0.002 mm is called:

(a) Gravel (b) Coarse Sand (c) Fine Sand (d) Silt

11. The soil particles less than 0.002 mm is:

(a) Gravel (b) Clay (c) Fine Sand (d) Silt

12. The percentage of water in garden soil is:

(a) 10 (b) 20 (c) 25 (d) 50

13. Soil composed of silicates (Si_2O_3) containing Al and one or more of K, Mg. Fe. H is:

(a) Quartz (b) Feldspar (c) Pyroxene (d) Mica

14. The soil with hard crystals is:
(a) Quartz (b) Feldspar (c) Pyroxene (d) Mica

15. The soil composed of silicates of Fe and Mg is:
(a) Quartz (b) Olivine (c) Pyroxene (d) Mica

16. The material formed by recently fallen leaves is called:
(a) Litter (b) Duff (c) Leaf mold (d) None

17. The layer present below the duff is:
(a) Litter (b) Duff (c) Leaf mold (d) None

Answers 1. (a) 2. (b) 3. (b) 4. (d) 5. (a) 6. (a) 7. (a) 8. (d) 9. (a) 10. (d) 11. (b) 12. (c) 13. (d) 14. (c) 15. (b) 16. (a) 17. (c)

Fill in blanks

1. The physical and biological condition under which an organism lives is called ______.
2. The plants which grow best in full sunlight are called ______.
3. The plants which grow best at lower light intensities are called ______.
4. The weathered layer of the earth crust is called ______.
5. Soil microorganisms like ______ and fungi are responsible for decay of organic matter.
6. ______ lives in leguminous roots.
7. The soil containing 100% organic matter is known as ______.
8. This decomposed material is called raw humus or ______.
9. Plants grow in water reservoirs like ponds, lakes streams or rivers are called ______.
10. The ______ loving plants are amphibiophytes.
11. Light convert starch of the guard cells into ______.
12. The response of plant to 24 hour day night cycle is called ______.
13. The plants which live in extremely low temperature are called ______.
14. Rise in temperature ______ the relative humidity of the air.
15. Photosynthesis increases with rise in temperature up to ______C.
16. Temperature and ______ determine the general distribution of vegetation.
17. The weathered layer of the earth crust is called ______.
18. The study of soil in their natural environment is called ______.
19. The study of influences of soils on living things, particularly plants is called ______.
20. The breakdown of soil is called ______.
21. The process of decomposition with the help of water is called ______.
22. Crumb is spheroidal soil is ______.
23. There are ______ master horizons in the soil profile.
24. The arrangement of soil particles in layers is called soil ______.
25. ______ is the common form of silica or SiO_2
26. Mica is composed of ______ containing Al and one or more of K, Mg. Fe. H.
27. *Clostridium* live in aerated and ______ soils.
28. *Rhizobium* lives in leguminous ______.
29. The process of humus formation is called ______.
30. The material formed by recently fallen leaves is called ______.
31. A -humus formation is ______ raw humus.
32. A ______ -humus formation is intermediate between mor and mull.

Ans: 1.environment, 2. Heliophytes, 3. Sciophytes, 4. Soil, 5. Bacteria, 6. *Rhizobium*
7. peat, 8. Mor, 9. Hydrophytes, 10. Moisture, 11. Sugars, 12. Photoperiodism, 13.

Microtherms, 14. Decrease, 15. 25°, 16. Moisture, 17. Soil, 18. Pedology, 19. Edaphology, 20. Weathering, 21. Hydrolysis, 22. Porous, 23. 5, 24. Profile, 25. Quartz, 26. Silicates, 27. Unaerated, 28. Roots, 29. Humification, 30. Litter, 31. Mor, 32. moder

True/False

1. Visible spectrum is divided into seven colours.
2. The wavelengths below 400 are called ultraviolet rays.
3. The wavelength above 750 millimicrons is called ulta violet rays.
4. The plants which grow best in full sunlight are called heliophytes.
5. The plants which grow best at lower light intensities are called sciophytes.
6. Light convert starch of the guard cells into proteins.
7. The response of plant to 24 hour day night cycle is called photoperiodism.
8. Water is frozen into ice crystals in the intercellular spaces.
9. The plants which live in extremely low temperature are called macrotherms.
10. Photosynthesis increases with rise in temperature up to 25°C.
11. Temperature and moisture determine the general distribution of vegetation.
12. The weathered layer of the earth crust is called land.
13. The study of soil in their natural environment is called pedology.
14. The study of influences of soils on living things, particularly plants is called edaphology.
15. The breakdown of soil is called weathering.
16. The process of decomposition with the help of water is called oxidation.
17. Igneous rocks are formed by the cooling of magma.
18. The soil transported by gravity or wind is known colluviall soil.
19. Soil transported by water is called alluvial soil.
20. Soil transported by glaciers is glacial soil or alloival till.
21. Relative proportion of the soil particles size is known as soil texture.
22. Soils with the finest texture are called clay soils.
23. The soils with the coarsest texture are called sands
24. This process of crumb formation of clay is called hydrolysis.
25. Crumb is spheroidal soil is porous.
26. There are 7 master horizons in the soil profile.
27. The arrangement of soil particles in layers is called soil profile. A soil horizon makes
28. Clay is the common form of silica or SiO_2
29. Mica: It is composed of silicates (Si_2O_3) containing Al and one or more of K, Mg. Fe. H.
30. *Rhizobium* lives in leguminous roots.
31. The process of humus formation is called humification.
32. The material formed by recently fallen leaves is called mor.
33. A mor-humus formation is raw humus.
34. A mor -humus formation is intermediate between mor and mull.
35. Precipitation includes rain, snow, hail and dew.
36. The moisture loving plants are amphibiophytes.
37. The desert plants are called hydrophytes.

Ans: 1. T, 2. T, 3. F. infra red, 4. T, 5. T, 6. F. sugars, 7. T, 8. T, 9. F. microtherms, 10. T, 11. T 12. F. soil, 13. T, 14. T, 15. F. hydrolysis, 16. T, 17. T, 18. T, 19. T, 20. F. glacial, 21. T, 22. T, 23. T. 24. Flocculation, 25. T. 26. F. 5. 27. T, 28. F. Quartz, 29. T. 30. T. 31. T, 32. F. litter. 33. T, 34. F.moder, 35. T. 36. T. 37. F. xerophytes

Chapter 4

POPULATION ECOLOGY

Syllabus

1. A brief introduction: History and background
2. Seed dispersal, Seed bank, demography, reproductive strategy

POPULATION

The number of individuals of specie living in the same area at the same time is called population. Population has two aspects: number of individuals of a specie and area occupied by them. Clarke (1954) formed two types of populations:

a) **Monospecific:** Population of only one specie living in the same area is called Monospecific.

b) **Mixed or Polyspecific:** Populations of different species living in the same area are called Polyspecific.

Population has following characteristics:

1) Density (mass)

The number of individuals living in a unit area is called density. For example number of wheat plants in an acre etc. Large organisms like trees may be expressed as 100 trees per hectare. On the other hand, smaller organisms like phytoplankton (algae) may be expressed as 1 million cells per cubic meter of water. The unit of density varies in different species. Density may be numerical density or biomass density.

a) **Numerical density:** Number of individuals is taken in numerical density. It is used when individuals in a population have uniform sizes.

b) **Biomass density:** Biomass (wiegt) per unit area or volume is taken in biomass density. It is used when size of individuals is variable sizes of trees.

Density has two types: (Both)

a) **Crude density:** It is the number of individuals or biomass per unit of total area inhabited by the specie (tot. area) (only individual area present?/actual)

b) **Ecological density:** It is the number of individuals or the biomass per unit of that area actually inhabited by the individual of the specie.

Generally, organisms clumped into groups. They are rarely uniformly distributed. Therefore, concept of crude and ecological density is used. For example, certain species of plants like *Cassia tora* are crowded in shady patches. Other areas are without plants. Thus density calculated in shady area and open areas is crude density. On the other hand, density of only shady area is ecological density. → of space

2. Population dispersion or spatial distribution

Dispersion is the spatial pattern of individuals in a population relative to one another. It is the random pattern of distribution of individual of a population over space. In nature, different biotic interactions influence the abiotic factors. There are three basic population dispersions.

a) **Regular or uniform dispersion:** Here the individuals are more or less spaced at equal distance from one another. This is rare in nature. But it is common in crop fields like rice or wheat fields. Uniform distribution occurs when severe competition is present among the plants in a forest.

b) **Random dispersion:** Here the position of one individual is unrelated to the position of its neighbors. In this case, the individuals are distributed randomly. These are also less common in nature. For example, tree of shisham grow randomly in the field.

c) **Clumped dispersion:** Here individuals [illegible] aggregate into patches. These patches are [illegible] interspersed with no or few individuals. In this case, the individuals occur in scattered groups. Most populations exhibit this dispersion. Daily and seasonal weather and reproductive pattern causes clumping of trees.

3. Natality or birth rate

born

The rate at which the new individuals are added to a population in a unit time is called Natality. Population increases due to natality. Natality rate may be expressed as number of organisms born per reproductive organism (female plant) per unit time. There are two types of natality:

a) **Maximum natality:** It is also called absolute natality. It is theoretical maximum production of new individuals under ideal conditions. It means that there is no ecological limiting factor. Reproductive becomes limited only by physiological factors. It is constant for a given population. Such natality is not possible in nature. It is only is used for comparison.

when
Actual factor
Facts are consider

b) **Ecological natality:** It is also called realized natality. In this case, a population increases under an actual, existing specific condition. Thus it takes into account all possible existing environmental conditions. It is also called fertility rate.

Natality is expressed as:

$$\text{Absolute natality rate (B)} = \frac{\Delta N_n}{\Delta t}$$

$$\text{Ecological natality (b)} = \frac{\Delta N_n}{N\Delta t} \quad \text{(It is natality rate per unit time)}$$

Here

N = initial number of individuals

n = new individuals in the population

t = time

4. Mortality or death rate

divide

The rate at which the individuals are lost by death in a unit time is called mortality.

If the birth rate is more than the death rate, then population is increasing. If the birth rate is less than death rate (~~Death~~), the population is decreasing. It has two forms:

a) **Minimum mortality:** It is also called specific potential mortality. It represents the theoretical minimum loss under ideal or non-limiting conditions. It is constant for a population.

b) **Ecological or realized mortality:** It is actual loss of individuals under a given environmental conditions. It is not constant for population. It varies with population and environmental conditions like diseases, drought or other ecological hazards.

5. Age structure or distribution

The population of individuals of different ages in the group is called age distribution. Individuals are of different ages in most of the populations. The proportion of individuals in each age group is called age structure of the population. The age groups are prereproductive, reproductive and post reproductive. The ratio of different age groups is determined. It gives the current reproductive status of the population.

Age pyramids → distributions

The model representing geometrically the populations of different age groups in the population of any group is called age pyramids. According to Bodenheirmer (1938), there are following three types of age pyramids:

a) **A pyramid with a broad base (triangular structure):** It shows high percentage of young individuals. Birth rate is high in such populations. Each successive generation is more numerous than the preceding one. Thus it forms a pyramid with broad base. It occurs in many phytoplanktons in water.

b) **Bell-shaped polygon:** It shows a stationary population. Such population has equal number of young and middle aged individuals. Here growth is slow and stable. Here pre-reproductive and reproductive age groups are more or less equal in size. The post-reproductive group remains the smallest. It is found in many trees.

c) **An urn-shaped structure:** It indicates low percentage of young individuals. It shows a declining population. Here birth rate is dangerously reduced. Thus prereproductive group become much smaller. Such situation occurs in conditions of stress like drought etc.

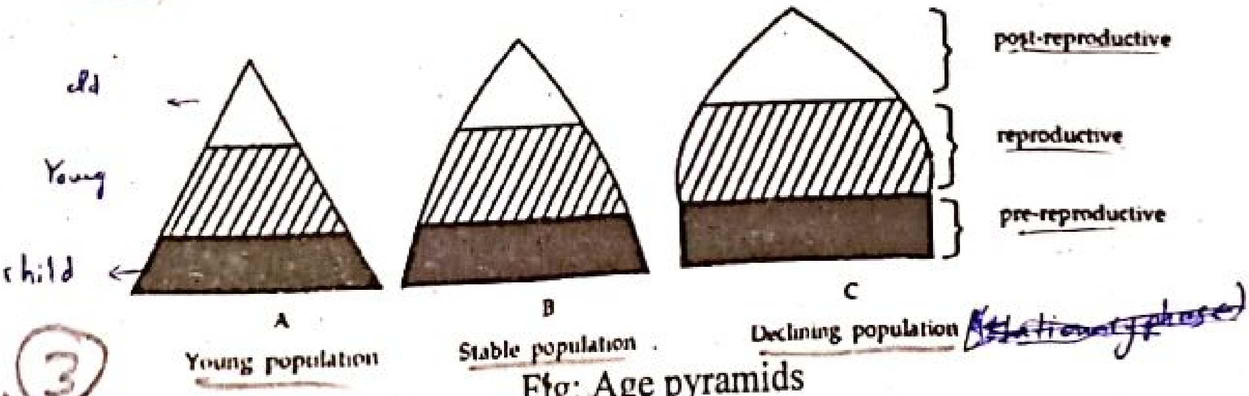

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Fig: Age pyramids

6. Population growth

The number of individuals of population or biomass increased in unit time is call population growth. There are different patterns of population growth in plants. Some plants have rapid growth rate. They increase rapidly and reached the carrying capacity of the field. Then their death starts due to competition and shortage of nutrients. Some populations have uniform growth rate. Their death rate is equal to birth rates. Therefore, the population remains uniform.

(species)

Same indivi

7. Competition

The individuals compete with each other for space and nutrients. **Intraspecific competition** occurs within same population. Individuals of the same specie compete with each other. It is more severe competition because all the individuals have same ecological niche. **Interspecific competition** occurs between different species. It is less sever. Different species of plants have different adaptations to compete with the other species.

species

HISTORY AND BACKGROUND OF POPULATION ECOLOGY

1. **History of man:** Man is on this earth for about 40,000 years. Early man had a niche in the ecosystem. It was a primary consumer. It feeds on roots and fruits. Later it became secondary consumer and predator. It started hunting and killing his prey. Thus a new man evolved. He changed his niche in the ecosystem. Communities of plants and animals were also modified.
2. **Origin of human culture:** Human culture started over 5000 years ago. The development of industry, technology and modern medicine took place in the last 200 years. Modern man can modify his external environment. He constructs his home to live. He made cloths to wear. He releases heat energy from fossils fuel. Thus physical environment can not affect him. Therefore, he can lives in almost any climate.
3. **Demand for food:** The demand for food has increased with the increase of population. Thus humans convert the natural ecosystem into artificially maintained agricultural ecosystem. The natural variety of plants and animals is destroyed and these plant and animals are replaced with species useful to humans. Sometimes, these agricultural ecosystems are mismanaged. So the total productivity of the regions may fall below the original ecosystem. The dust bowl of North America, desertification in Africa and destruction of tropical rain forests are well known examples.
4. **Need of ecological studies:** All these changes require ecological studies. These studies are made in population ecology. In population ecology we study different factors involved in the rise and fall of the populations. It also gives how different populations tend to increase beyond their mean.
5. **Origin of population ecology:** Population is the study of one species occupying an area. But a population depends on other resources for food and shelter. Therefore, population ecology interacts with community ecology. The characteristics of a population are shaped by their interaction with environment. Natural selection modifies these characteristics. Thus population ecology also has close relationship with the evolutionary ecology. Thus population ecology is not an isolated subject. It includes many other aspects of ecology.

SEED DISPERSAL

Imp

Seed dispersal is the movement or transport of seeds away from the parent plant. Plants have very limited mobility. Thus they depend upon a variety of dispersal vectors to transport their seeds. Seeds can be dispersed away from the parent plant individually or collectively. Dispersal mechanism determines the patterns of seed dispersal. This has importance for the demographic and genetic structure of plant populations. It also has importance in migration patterns and species interactions. Seeds are dispersed to far off places. Thus the genes of a population of plant are dispersed to other places. There are different methods of dispersal of seed:

A Dispersal by Wind

Whole fruit or individual seeds may disperse by wind. Such seeds are light in weight. Seed are of following types on the basis of dispersal by wing. These are minute seeds, flattened fruits or seeds, wing like outgrowths, feathery appendages and censor mechanisms.

1. **Minute seeds:** The seeds of orchids are very small. They have a light, inflated outer covering. These dust-like seeds are blown by the wind for great distance.
2. **Wings:** In some cases, seeds and other whole fruits are flattened. Some may have wing-like outgrowths. Some may be both flattened and winged. These structures help in dispersal of seeds. Its examples are fruits of ash, maple, etc.
3. **Feathery appendages:** Seeds or fruits of some plants may have feathery appendages. These appendages greatly increase their buoyancy. Thus they are frequently carried by the wind to considerable altitudes. These feathery appendages are characteristic of the seeds of many compositae.
4. **Censor mechanisms:** The capsules of many plants open in different ways. Thus the seeds can escape when the capsules are violently shaken by a strong wind. It occurs in fruits like poppy, etc. This mechanism scatters the seeds. Some seeds may have a flat shape or winged outgrowths. They escape when there is a strong wind. Wind blows them to considerable distances.

B Dispersal by Water

Many seashore and aquatic plants disperse by water. They have different adaptations for dispersal by water. Whole fruit or the seed may be adapted for floating. The pericarp of a fruit may be composed of light tissue. In some cases, fruit may be inflated. The coconut is an excellent example of a fruit. It has a light pericarp. Floating seeds may contain a mass of light tissue of large air spaces. In the lotus fruit, the torus is a greatly enlarged mass of loose, air-filled tissue. They float readily. Many seeds are not especially fitted for floating. They may occasionally float for short distances.

C Dispersal by Animals

There are two ways of dispersal of seeds by animals. Some fruits have fleshy fruits. A portion of such fruits is eaten by the animals. Any dry fruits adhere to animals.

1. **Fleshy fruits:** Fleshy fruits are eaten by animals. The fleshy part such fruits may be eaten without injury to the seed. In many cases the seed coat is very hard.

2. **Stony seeds:** Seed is protected by stony endocarp in drupes. A seed is protected by the stony endocarp. Thus the seed may pass without injury through the digestive tract of an animal. Birds are particularly prominent in dispersing the seeds of fleshy fruits. Sometimes, they eat the fleshy portion of a fruit and throw the seeds away. Dry fruits are often carried off for food by seed-eating animals. They lose them in one way or another and leave them to grow.
3. **Adhesive fruits:** Many dry fruits have hook like appendages (e.g., Cosmos, Bidens, Mimosa pudica, Triumfetta, etc.). It is fitted for grasping the hair of animals. Animals carry them and distribute the seeds. The fruit may adhere to clothing and dispersed by man. Some seeds and fruits have a sticky covering. It adheres to the hair of an animal. Fruits of Chinese forget-me-not adhere by sticky book like appendages. Feathery appendages are capable of adhering to fur. They may fly on the wind.

D. Dispersal by Explosive Mechanism

1. **Minute seeds:** Many plants have minute seeds. They are caught in mud. Thus these seeds adhere to the feet or other parts of birds or other animals. The animals disperse them.
2. **Explosion mechanism:** Many fruits explode when ripe and scatter the seeds. This method of dispersal is found in members of the bean family. The explosive forces are due to stresses arising from the drying of the valves of the pod.

The balsam has somewhat fleshy capsules. These are very turgid. Sometimes, these are disturbed by contact. Now the segments of the pericarps roll up with considerable force. Therefore, they scatter the seeds. An unusual explosive mechanism is found in the squirting cucumber.

Ecological significance of dispersal of seed

1. Population of specie establish in another biome by dispersal of seeds. (after disaster)
2. Seeds are importance source of primary and secondary succession.
3. Seeds are food of many herbivores and omnivores. So they have role in food chain.
4. Dispersal of seed in different places decreases the intraspecific competition among the local vegetation.

Call?

SEED BANK

Imp

Soil To (Store)

Place

The storage of seed in the soil is called seed bank. Seeds fall on the soil. They are buried in the soil. Some seeds germinate to form new plants. Some seed does not grow and remain dormant. These seeds form the seed bank. Plant seeds can remain dormant for many years. This property of the seed has great significance for the survival of plants. Seed bank has following significance for the plants:

1. Sometimes, plants fail to develop sufficient number of seeds due to unfavorable conditions. The seed from seed bank grow to compensate this deficiency. In this way, population of the plant is not affected.
2. Sometimes, unfavorable conditions persist for many years. These conditions are drought, high temperature, alkalinity, salinity and water logging. The land becomes totally unfavourable for vegetation for many years. Thus seeds are not produced for

General Def:
Place where seed are stores insitue or extsitue for short term use in forming or long term preservation to preserve genetic diversity hence a type of gene belt?

many years. After some years, the conditions become favourable. Now seeds from the seed bank grow and maintain the population of specie.

3. Sometimes, fire completely destroys the plants. Thus they are unable to produce seed. Seeds from seed bank grow and develop new vegetation.
4. Seed bank play an important role in ~~primary~~ Secondary succession.
5. Seed bank regulates the population size of the plant in normal conditions.

DEMOGRAPHY ∝ ∝

The study of the vital statistics that affect population size is called demography. Birth rate and death rate vary among subgroups within a population. This birth rate and death rate control the population size. Addition occurs due to birth and immigration. Deaths (Mortality) and emigration decreases the population. Certain vial factors like age structure and sex ratio affect the population size. These are studied in demography.

1. Age structure

The relative number of individuals of each age in population is called age structure. Mostly average lifespan of individuals in a population is greater than time it takes to mature or reproduce. Therefore, the generation overlaps. It gives different age structure in a population. Age of plant can be determined by **annual growth rings.**

Each age group has characteristic birth and death rate. Young and old individuals have more chance to die than intermediate age group. The intermediate age groups are stronger. They have ability to reproduce. For example the death rate is highest in young plants and old plants. Thus the intermediate populations have highest birth rate. Such population increases rapidly. The populations with large number of older individuals shows decline.

The age groups are prereproductive, reproductive and post reproductive. The ratio of different age groups is determined. It gives the current reproductive status of the population.

Age pyramids

The model representing geometrically the populations of different age groups in the population of any group is called age pyramids. According to Bodenheirmer (1938), there are following three types of age pyramids:

d) **A pyramid with a broad base (triangular structure):** It shows high percentage of young individuals. Birth rate is high in such populations. Each successive generation is more numerous than the preceding one. Thus it forms a pyramid with broad base. It occurs in many phytoplanktons in water.

e) **Bell-shaped polygon:** It shows a stationary population. Such population has equal number of young and middle aged individuals. Here growth is slow and stable. Here pre-reproductive and reproductive age groups are more or less equal in size. The post-reproductive group remains the smallest. It is found in many trees.

f) **An urn-shaped structure:** It indicates low percentage of young individuals. It shows a declining population. Here birth rate is dangerously reduced. Thus prereproductive group become much smaller. Such situation occurs in conditions of stress like drought etc.

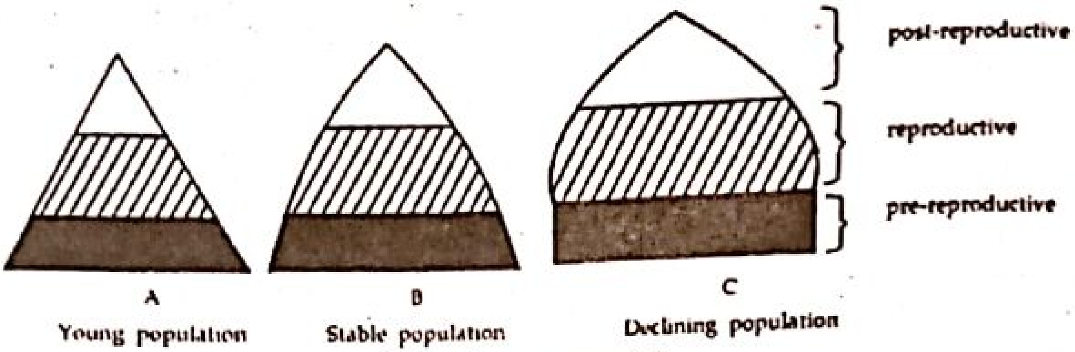

Fig: Age pyramids

2. Generation time

The average span between the birth of individuals and the birth of their offspring is called generation time. It is an important demographic feature. It directly affects the population size. There are two types of generation times:

(a) **Short generation time:** There is fast growth rate in populations with shorter generation time. Such populations have both high birth rate and death rate. Its example is annual plants

(b) **Long generation time:** They have slow growth rate. Their birth rate is equal to death rate. Its example is annual plants.

3. Sex ratio

The proportion of the individual of each sex in a population is called sex ratio. It is also an important demographic statistic. It affects the population growth rate. The birth rate is related to number of females in a population. Single male can provide sperm to many females. Therefore, the number of males is less significant for birth rate. For example, dates have separate male and female plants. Only one or two male plants are sufficient to fertilize female plants of all the gardens.

Applications of demography

Demography is used to develop life tables and survivorship curves.

1. Life tables

The tables showing mortality summaries of a population is called life table. Cohorts are used to develop these tables. **Cohort is a group of individuals of same age from birth till their death.** Essential data is taken for the living individuals for sampling time. This sampling time is taken one year for most of the species. This data is put in table with different columns. Life tables show following factors of demography:

(a) The variation of mortality with age over a time period. This time period is equal to maximum life span of this population.

(b) Eggs produced by female of particular age. It is called **fecundity.**

(c) Birth rate in sampling time.

2. Survivorship curves

A plot of the numbers of cohort alive at each age group is called survivorship curve. These are classified into three general terms:

(a) **Type I:** It is a flat curve. It shows low death rates during early and middle age. The death rates increase among older age groups. Therefore, this curve drops steeply. It is shown by human population.

(b) **Type II:** It is intermediate between type I and type III. Their mortality is constant throughout the life span. It is shown by annual plants.

(c) **Type III:** This curve drops sharply at the left of the graph. It shows very high death rate in the young individuals. But then it becomes flat. It is found perennial plants.

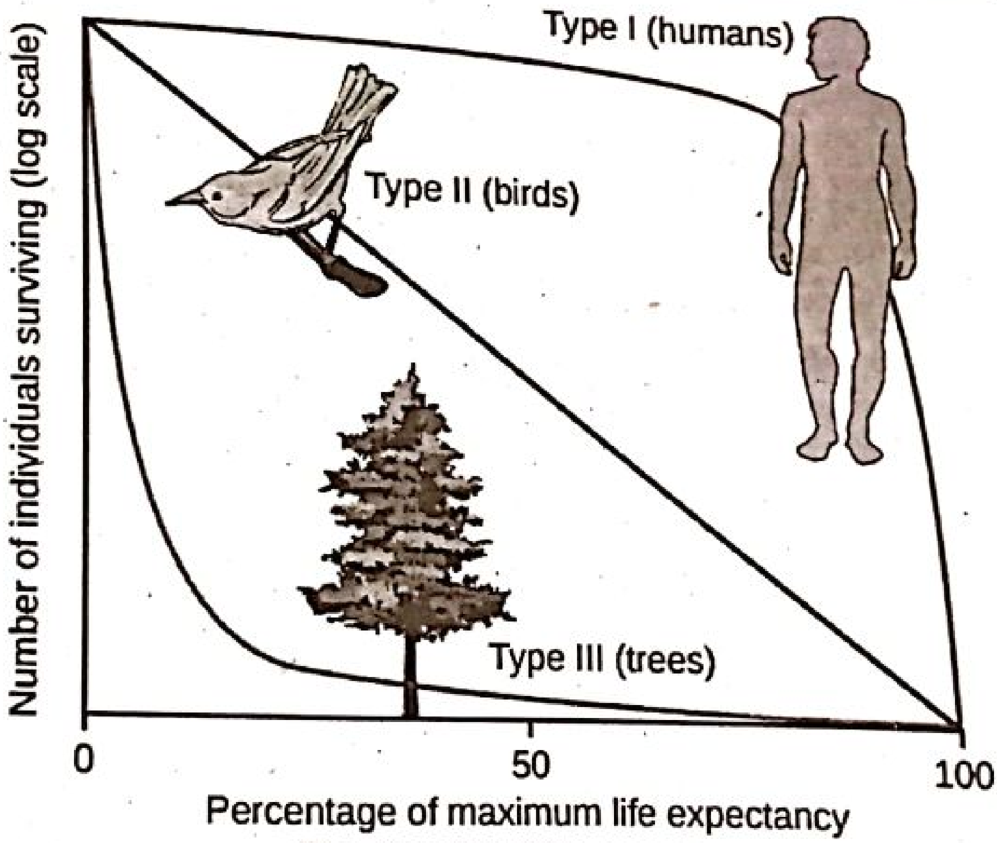

Fig: Survivorship curves

REPRODUCTIVE STRATEGY

The basis of reproductive strategies is the survival of plant in particular habitat. These reproductive strategies are developed by natural selection. Every organism reproduces to maintain their specie. Each organism wanted that most of its offering survive in the next generation. Therefore, they adapt different reproductive strategies. Reproduction may be asexual or sexual. Different organisms have different reproductive strategies. For example

a) Some species of oak does not reproduce until it becomes 20 year old. Then it produces large number of seeds each year.

b) Annual desert wildflowers produce many small seeds and then die.

The reproductive strategies depend on three factors:

1. **Clutch size**

The number of offspring or seeds produced at each reproductive cycle by a plant is

called clutch size. For example, a plant produces 1000 seeds in its one season. It is its clutch size. Generally plants which large clutch size (produce large number of seeds) produce small seeds or fruits. Their seeds and fruits have small amount of stored energy. Wheat produces a large number of small seed. The plants which have small clutch produce larger seeds and fruits like mangoes.

2. Number of reproductive cycle per lifetime

There are two types of plants:

(a) Some plants show few reproductive cycles in their life time. Such plants use most of their stored energy for growth and maintenance function. They grow well and they have large size. For example, the cones of the pines mature in three years. So it has less number of reproductive cycles in its life time but it has large size. Some annual plants reproduce only once during their life time.

(b) Other plants reproduce many a times during their life time. They divided their energy budget for growth, maintenance and reproductive. These plants generally have small size.

3. Age at first reproduction

Age of first reproduction has great effect on the age of plant. Generally, annual plants start reproductive very early. So they have very life span of only one season. On the other hand, the plants which start reproduction late have long life span. For example most of mangoes start reproduction at the age of five to 10 years. So it has long life span.

Types of life cycles on the basis of reproductive strategies

There are two types of plants on the basis of reproductive strategy:

1. **Opportunistic life cycle:** In this case, the plants produce large number of seeds in a single reproductive cycle. They store small amount of food in their seed. Survivorship is generally low in these species. The population size of these plants fluctuates rapidly. When environmental conditions are favourable, large number of seed grows and size of population greatly increased. When conditions are unfavourable, only few seeds are able to grow. Thus size of the population remains small. Most of the annual plants like dandelion show opportunistic life cycle.
2. **Equilibrial life cycle:** In this case, the plants produce small number of seed in single season. They have large amount of stored food in seed. Most of these seeds grow to form plants. Their populations do not fluctuate rapidly. Most of the annual plants like coconut palm show this type of life cycle.

DEFINITIONS AND KEY

TERMS	DEFINITIONS
Population	The number of individuals of specie living in the same area at the same time is called population.
Monospecific	Population of only one specie living in the same area then it is called Monospecific.

Mixed or Polyspecific	Populations of different species living in the same area are called Polyspecific.
Population density	The number of individuals living in a unit area is called density.
Mortality	The rate at which the individuals are lost by death in a unit time is called mortality.
Dispersion	It is the random pattern of distribution of individual of a population over space
Population growth	The number of individuals of population or biomass increased in unit time is call population growth.
Seed bank	The storage of seed in the soil is called seed bank.
Demography	The study of the vital statistics that affect population size is called demography.
Age structure	The relative number of individuals of each age in population is called age structure.
Generation time	The average span between the birth of individuals and the birth of their offspring is called generation time.
Sex ratio	The proportion of the individual of each sex in a population is called sex ratio.
Life tables	The tables showing mortality summaries of a population is called life table.
Cohort	Cohort is a group of individuals of same age from birth till their death.
Survivorship curve	A plot of the numbers of cohort alive at each age group is called survivorship curve.
Clutch	The number of offspring or seeds produced at each reproductive cycle by a plant is called clutch size.

MODEL SUBJECTIVE QUESTIONS

1. **What is population? Give its characteristics.**
2. **Give history and background of population growth.**
3. **Write note on seed dispersal.**
4. **What is demography? Give its different aspects.**
5. **Give applications of demography.**

SHORT QUESTIONS

Differentiate between Monospecific and Polyspecific populations.

ns: Population of only one specie living in the same area then it is called Monospecific. Populations of different species living in the same area are called Polyspecific.

What is population density? Give examples.

Ans: The number of individuals living in a unit area is called density. For example number of wheat plants in an acre etc. The unit of density varies in different species.

3: **Differentiate between crude and ecological density?**
Crude density is the number of individuals or biomass per unit of total area inhabited by the specie. Ecological density is number of individuals or the biomass per unit of that area actually inhabited by the individual of the specie.

4. **What is Natality?**

Ans: The rate at which the new individuals are added to a population in a unit time is called Natality.

5. **What is mortality?**

Ans: The rate at which the individuals are lost by death in a unit time is called mortality. If the birth rate is more than the death rate, then population is increasing. If the birth rate is less than death rate, the population is decreasing.

6. **What is meant by competition?**

Ans: The individuals compete with each other for space and nutrients. Intraspecific competition occurs within same population. Individuals of the same specie compete with each other. It is more severe competition because all the individuals have same ecological niche.

7. **What is the role of seed in the dispersal of seeds?**

Ans: Most of the seeds are enclosed in the fruits like mango, guava and dates etc. The animals eat the flesh of fruit and throw away the seeds. Some seeds are not digested in the gut of animals. So they are thrown at different places with feces.

8. **Give three significance of dispersal of seeds.**

Ans: Population of specie establish in another biome by dispersal of seeds. Seeds are importance source of primary and secondary succession. Seeds are food of many herbivores and omnivores. So they have role in food chain.

9. **What is seed bank? Give its significance.**

Ans: **The storage of seed in the soil is called seed bank.** Seeds fall on the soil. They are buried in the soil. Some seeds germinate to form new plants. Some seed does not grow and remain dormant. These seeds form the seed bank. Plant seeds can remain dormant for many years. This property of the seed has great significance for the survival of plants.

10. **Define demography.**

Ans: The study of the vital statistics that affect population size is called demography.

11. **What are the effects of short generation time?**

Ans: **Short generation time:** There is fast growth rate in populations with shorter generation time. Such populations have both high birth rate and death rate. Its example is annual plants.

12. **What are generation time and cohort?**

Ans: The tables showing mortality summaries of a population is called life table. Cohorts are used to develop these tables. Cohort is a group of individuals of same age from birth till their death.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. **The number of individuals living in a unit area is called:**

(a) Density (b) Natality (c) Mortality (d) Dispersion

2. The rate at which the new individuals are added to a population in a unit time is:

(a) Density (b) Natality (c) Mortality (d) Dispersion

3. The rate at which the individuals are lost by death in a unit time is called mortality:

(a) Mortality (b) Natality (c) Density (d) Dispersion

4. The random pattern of distribution of individual of a population over space is:

(a) Natality (b) Dispersion (c) Density (d) Mortality

5. The number of offspring or seeds produced at each reproductive cycle is:

(a) Clutch (b) Natality (c) Density (d) Dispersion

Answers: 1. (a) 2. (b) 3. (a) 4. (b) 5. (a)

Fill in blanks

1. Number of individuals of specie living in the same area at the same time is called ________.
2. The number of individuals living in a unit area is called ________.
3. Number of individuals or biomass per unit of total area inhabited by specie is _______ crude.
4. The number of individuals or the biomass per unit of that area actually inhabited by the individual of the specie is called __________ density.
5. The rate at which the individuals are lost by death in a unit time is called __________.
6. Number of individuals of population or biomass increased in unit time is call ______ growth.
7. The relative number of individuals of each age in population is called _________ structure.
8. Average span between birth of individuals and birth of their offspring is called ______ time.
9. ______ is the spatial pattern of individuals in a population relative to one another.
10. In ______ dispersion position of one individual is unrelated to the position of its neighbors.
11. Maximum natality is also called ______ natality.
12. Ecological natality is also called ______ natality.
13. The rate at which the individuals are lost by death in a unit time is called ______.
14. Intraspecific ______ occurs within same population.

Ans: 1. Population, 2. Density, 3. Crude, 4. Ecological, 5. Mortality, 6. Population, 7. Age, 8. Generation, 9. Dispersion, 10. Random, 11. absolute, 12. Realized, 13. Mortality, 14. competition

True/False

1. Number of individuals of specie living in the same area at the same time is called population.
2. The number of individuals living in a unit area is called biomass.
3. Biomass per unit area or volume is taken in biomass density.
4. Dispersion is the spatial pattern of individuals in a population relative to one another.
5. In uniform dispersion position of one individual is unrelated to the position of its neighbors.
6. Maximum natality is also called absolute natality.
7. Ecological natality is also called absolute natality.
8. The rate at which the individuals are lost by death in a unit time is called mortality.
9. Intraspecific competition occurs within same population.
10. Seed band is the movement or transport of seeds away from the parent plant.
11. The storage of seed in the soil is called seed bank.
12. The relative number of individuals of each age in population is called age structure
13. Cluch is a group of individuals of same age from birth till their death.

Answers: 1. T. 2. F. density, 3. T, 4. T, 5. F. random, 6. T, 7. F. realized, 8. T. 9. T. 10. F. dispersal, 11. T. 12. T. 13. F. Cohort

Chapter 5

COMMUNITY ECOLOGY

Syllabus

1. Concepts of plant community, attributes
2. Sampling methods
3. Succession – history, concept, development and modern theories of succession
4. Brief concept of productivity
5. Local vegetation

Bulkt

CONCEPTS OF PLANT COMMUNITY

The populations of different species living in the same habitat are called community. According to Oosting (1956), plant community is an aggregation of individuals with mutual relationships among themselves and to their environments. Thus community has two parts:

1. Mutual Relationship among Individuals

It includes all the direct or indirect effects of the organisms on each other. Competition is the most important effect. A forest is composed of different kinds of plants. It has huge trees, large shrubs, small shrubs and ground flora etc. Survival of lower layer of plants depends upon the shade of the trees above them. The huge trees provide adaptation for the undergrowth.

Fungi and bacteria are also a part of the community. They also play an important role. These fungi and bacteria may be parasitic or saprophytic. They cause many diseases. Some of these diseases become much serious. These diseases can destroy whole community. There are certain symbiotic bacteria. They form a small nodule on the roots of the leguminous plants. These nitrogen fixing bacteria take free nitrogen from the air and combine it with other elements. They form nitrogenous compounds for the plants. The nitrogenous compounds of the plants are released in the soil. They are used by other plants.

2. Mutual Relationship with the environment

The plants adapt themselves in their habitat. Some plants can withstand heat or cold. Some plants require a large continuous supply of moisture. But some other plants require only a small amount of moisture. Thus the climate of a region controls the kind of plants. The complex of climatic factors determines the general vegetation types like grassland or forest. Thus climate of a region can be evaluated by observing the vegetation.

ATTRIBUTES OF THE PLANT COMMUNITIES

The attributes (characteristics) of a community are classified into three main groups: analytic, synthetic and physiognomic.

(A) Analytic characteristics

The characteristics which can be analyzed by quantitative or qualitative methods are called analytic characteristics. These may be qualitative or quantitative characteristics.

1. Qualitative Characteristics

The disruptive characteristics which cannot be measured are called qualitative characteristics. These includes following characteristics.

(i) **Kinds of Species or Floristic Composition:** A complete list of species is called floristic composition. It is essential for the study of a stand.

(ii) **Stratification: The plants occurring together with a similar ecology in definite strata are called stratification.** The size and number of these strata depends on the type of life form. Stratification of the community causes differences in requirement of trees, shrubs and herbs. They require different light intensity, temperature, moisture condition and organic content of the soil. Most temperate forest communities are composed of 3 - 4 strata.

- **Over story tree:** The upper stratum consist of relatively large over storey trees,
- **Crown:** Below these taller trees, there is a stratum of the crown or secondary under storey trees.
- **Herbaceous plants:** Below the secondary trees there is one or more layers of herbaceous plants.
- **Mosses or lichens:** Mosses or lichens may be present in the low layer on the ground. [illegible]

(iii) **Periodicity: The rhythmic phenomena related to seasonal changes is called periodicity.** These changes are growth, flowering, pollination, ripening of fruit and seed. Periodicity is controlled by different environmental factors like light, temperature etc.

(iv) **Vitality: The capacity of plants to complete its life cycle is called vitality.** Some species have low vitality and die soon. Some have high vitality. They complete their life span.

(v) **Sociability: The degree of aggregation of plants in nature is called sociability.** مجموعہ Sociability depends on life form, mode of reproduction, habitat condition and competition.

2. Quantitative characteristics

The characteristics which can be measured (by no.) are called quantitative characteristics. These include:

(i) **Density:** The number of individuals of specie in a unit area is called density.

(ii) **Relative density:** The proportion of a density of a specie to a stand as a whole is called relative density. (اندازہ)

(iii) **Abundance:** The estimation of individuals of a specie is called abundance.

(iv) **Cover:** The ground covered or shaded by the above ground parts of plant is called cover. Cover also includes **basal area**. The ground actually covered by crown is called cover.

(v) **Relative cover:** The proportion of the cover of a species to sum of the all the plant of all the species is called relative cover.

(vi) **Frequency:** The degree of occurrence of individuals of a species within an area is called frequency.

(vii) **Relative frequency:** The proportion of the total frequency of specie to the sum of the frequency of all the species in the area is called relative frequeny.

(viii) **Frequency classes:** Different classes are formed on the basis of relative frequencies. There are five frequency classes.

(B) Synthetic characteristics

→ not directly measured but derived from direct - e.g [illegible]

The generalization and integration of characteristics that derived from data of analytic qualities are called synthetic characteristics. In this case, data is arranged in tubular form. Then synthetic characteristics are studied. There are following synthetic characteristics:

(i) **Presence:** It is the uniformity of specie occurs in number of stands of the same type of community.

(ii) **Constancy:** A specie that occurs in 90% or more of the stand is called constant specie.

(iii) **Fidelity:** The relative occurrence of specie in an association or a group of related association is called fidelity.

(iv) **Dominance:** The species which have high number and large volume are called dominant species.

(C) Physiognomic characteristics

The general appearance or outlines of the stand or community are called physiognomic characteristics. It includes:

(i) **Physiognomy:** The appearance of stand is called physiognomy.

(ii) **Pattern:** The group of individuals with physiognomic contrast

(iii) **Life-form:** The vegetative appearance of the plant body and its longevity is called life-from. There are five principle life form classes.

- **Phanerophytes:** These plants include woody trees and shrubs. Their bud bearing shoots are elevated and exposed to the atmosphere. Example, Accaia sp.
- **Chamaeophytes:** They include wood or semi woody perennial under shrubs. The bud is above the ground but less than 25 cm high. Example Salvia sp.
- **Hemi-cryptophytes:** The perennating buds are half hidden in the surface of

soil. Example euphorbia.

- **Cryptophytes:** Their buds are in soil or under water, e.g. Hydrilla.
- **Therophytes:** It includes all the annual plants. Their only perennating buds are present in seeds.

SAMPLING METHODS Not theory (only practicals)

There are following two types of sampling methods:

(a) Transect method

A transect is a long rectangular sample plot. It is used to study variations in vegetation. Vegetation varies with the changing environments. These variations are caused by slope, exposure, edaphic and topographical irregularities. It also shows how one plant community is replaced by the other. Two types of transects are commonly used:

1. **Line Transect:** It is also called as line intercept method. In this case, plant species are recorded along a line. It is useful for dense. Vegetation. This method is rapid. It gives accurate information about the vegetation.

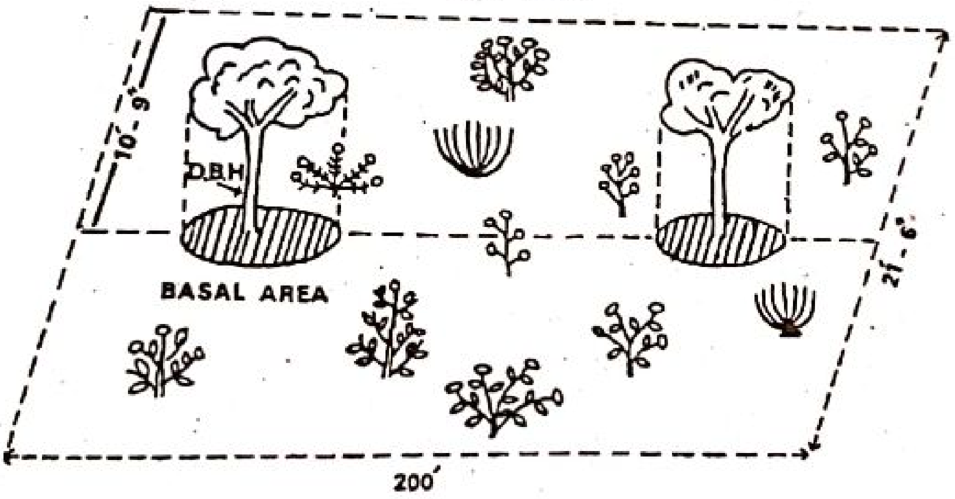

Fig: Strip method

2. **Strip Method:** It was introduced by Canfield (1941). It is very good method for sampling of forest shrubs or trees with crown cover. It is actually an improvement of line transect method. This sampling method requires measuring tapes, nails and a rod of ten feet and nine inches in length.

   200 feet long line is drawn with the help of a measuring tape from the starting point. An area of 10' - 9" is marked from all side of this line strip with the help of a rod. It makes the transect of 200' x 21 '—6", All species intercepted in this transect are recorded. The crown cover is taken by long stick. The stick is kept in perpendicular position. The upper end of the stick faces the periphery of the crown. The other end is pointing to the ground. Now the stick is moved downwards, so that it may touch the ground. Distance of this point to the trunk of the tree is taken. It gives us the radius of the circle. Then circumference is calculated. It is converted into cover with the help of conversion table. Frequency of the species is determined by the following formula:

$$\text{Frequency} = \frac{\text{Number of times a species is intercepted}}{\text{Total number of interceptions}}$$

3. **Bisects method:** It shows the vertical distribution of plants or profile of the vegetation. This distribution includes all the strata or layers of the community, from dominant trees, shrubs, herbs, climbers and ground flora. It is also used to study relative position of underground parts like rhizome, bulb, tuber and roots of each plant. Their relative positions are carefully measured. It is done by digging a trench in the community.

(b) Quadrat Method

A quadrat is a sampling unit used for the quantitative study of plant communities. It may be a square, rectangular or circular in shape. But rectangular plots are more useful. A quadrat can have any size. But generally, large quadrat is used for richer and heterogenous plant community. A number of quadrat should be taken during sampling. These quadrates should include all the possible variation. It should represent the data of all the vegetation.

1. Nails, cords and measuring tapes are required for making quadrat. Its size is fixed. Then the quadrat is laid down. It is fixed at four points with the help of nails. Cord is tightly tied to the four nails. At least 15-20 quadrats are taken. There are intervals of twelve steps between each quadrat.
2. The size, shape and number of quadrats have been determined. The quadrats are distributed in random, uniform, or stratified manner.
3. All the plant species inside the quadrats are recorded. Then number of individuals of each species is counted.
4. Their cover (circumference) is measured with the help of measuring tapes. The measured cover is then converted into square feet.
5. The community attributes are density, cover, and frequency and importance value. These attributes are calculated separately for each species by different formulae of density, cover and frequency.

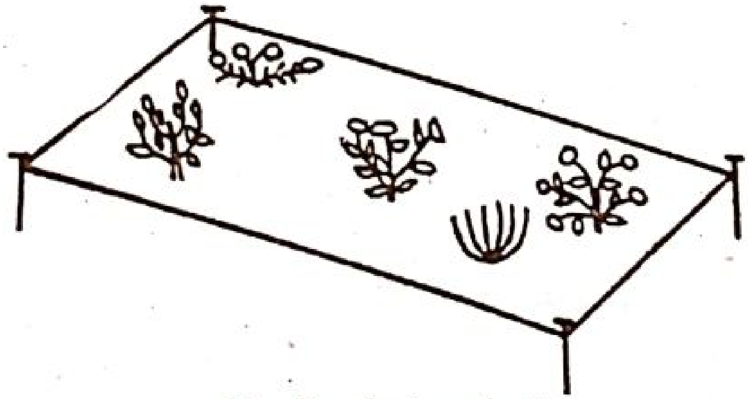

Fig: Quadrat method

Types of Quadrats

There are following types of quadrats:

1. **List quadrat:** In this quadrat a list of the organism found in a quadrat is formed. The organisms are listed by name. A series of list quadrates are formed. They gives a floristic analysis of the community.
2. **Count quadrat:** In this case, number of species found in a quadrate is recorded. These are used in forest survey. It also gives information about height, volume and basal area of the plants found in this quadrat.
3. **Cover quadrat:** In this case, actual or relative coverage is used. It is given in the form percentage of the area of the ground surface. This area is covered or shaded by plants.
4. **Chart quadrat:** In this case, quadrate study scale is used. It shows the location of individual plants. It gives an overall view of the community. It is used in the study of forests having large trees. Location of these trees is given in the quadrat.

PLANT SUCCESSION

That involves changes in structure and species composition with time

The process of community development is called succession. Community changes alter the ecosystem. This change favours the competitors. Thus the species replace one another. Finally a stable, self sustaining climax community is reached. Succession is a kind of community relay. In this case, plants and animals replace one another in a sequence. That sequence is predictable. The diverse and precise changes occur during succession. These changes take place according to changes in the environments in which succession occurs. Certain general stages of succession can be easily recognized.

Each succession begins by a few hardy invaders called pioneers. Succession ends with a diverse and relatively stable climax community. A community in which population of different species remain uniform is called climax community.

Two Major Forms of Succession

Succession of dry land takes place in two major forms, primary succession and secondary

1. Primary succession

The formation of ecosystem from bare rock, sand or clear glacial pool where previous life do not exist is called primary succession. In this case, the ecosystem is formed from the start. So it is a long process. It often requires thousands of years. Primary succession may start in two habitats

(a) **Hydrosere:** In this case the primary succession occurs in a pond.

(b) **Derosere:** In this case, succession occurs on a dry soil or rock.

(c) **Xerosere:** In this case, succession occurs on dry habitat. Plants growing in xeric condition are called **xerophytes.** Xerophytes can withstand prolonged periods of water shortage. Water is stored in large parenchyma tissue in **succulent** plants like cacti. Other xerophytes have leaf modifications for storage of water.

(d) **Psammosre:** The succession which occurs on sand dunes is called psammosere.

(e) **Halosere:** The succession which occurs on saline soil is called halosere.

2. Secondary succession

The formation of a new ecosystem after the disturbance of an existing ecosystem is called secondary succession. The disturbance may be in the form of forced fire or an abandoned farm field. The previous community leaves some mark in the form of improved soil and seeds. Therefore, secondary succession occurs more rapidly than primary succession.

Autogenic and Allogenic succession

1. Autogenic succession

The succession in which organisms themselves bring change in the environment during succession is called autogenic succession. The organisms cause change in the soil. These changes include accumulation of organic matter in form of humus or litter, alteration of soil nutrients and change in pH of soil. The structure of the plants themselves can also change the community. For example, larger species like trees produce shade on to the developing forest floor. It destroys the light-requiring species. Shade-tolerant species establish in the area.

2. Allogenic succession

The succession in which external environmental factors cause change in the environment during succession is called allogenic succession. Soil erosion, leaching or the deposition of silt can changes the soil. Similarly, clays can alter the nutrient content and water relationships in the ecosystems. Animals also play an important role in allogenic changes. They act as pollinators, seed dispersers and herbivores. They can also increase nutrient content of the soil in certain areas.

DEVELOPMENT OF SUCCESSION

The process of community development is called succession. Different stages are involved in the development of succession in a bare area. These stages are migration ecesis, aggregation, competition reaction and stabilization

1. Migration

All bare areas are without seed or other propagules. Seeds, spores and runners of the pioneer species migrate to this area. Following factors affect the migrations:

(a) **Mobility:** The ability of a species to move out of the present area is called mobility. It depends upon the nature of dispersal mechanism, number of seeds produced and the position of seeds or spores. Thus plant may be spore distributed, seed distributed, Fruit distributed, offshoot distributed and plant distributed.

(b) **Dispersing agents:** Migration also depends upon the dispersing agents. The important dispersing agents are water, wind, explosive mechanism, animals and man.

2. Ecesis

[illegible]

The phenomena of growth of propagules and their adjustments in the new surrounding area is called ecesis. It consists of three essential processes: germination, growth and reproduction.

(a) **Germination:** It is the first critical process of ecesis. The dormant embryo become active and begins to grow. Some seeds do not grow. They are called dormant seeds. They remain dormant for few weeks, months or even years. Dormancy may be due to both external and internal causes. Proper depth is also an important condition for successful seed germination.

(b) **Growth:** The seed grow and develop seedling. It is a very critical stage for the survival of plants. There is excessive competition among themselves and with other species. Competition may be for space, nutrition water and light.

(c) **Reproduction:** The plant grows and become mature. Then it develops different reproductive structures. Some plants reproduce asexually. Some undergo sexual reproduction.

3. Aggregation

The growth of plants in the form of colonies is called aggregation. The aggregation may be simple or mixed. The grouping and growing of offspring around the parent plant is called **simple aggregation**. The gradual spreading and mixing of the neighbouring plants is called **mixed aggregation**. It is caused due to process of migration.

4. Competition

The struggle for existence between the plants is called competition. The simple and mixed aggregation causes competition. Sometimes, two plants demands light nutrients or water in excess of the supply. It causes competition between these two plants. It is universal characteristics of all plant communities. It increases with increase in population density. There are two types of competition:

(a) **Intraspecific Competition:** The competition within the individual of the same one species is called intraspecific competition. These individuals have same demands. So it is more severe.

(b) **Interspecific competition:** The competition between different species it is called interspecific competition. Different species have different requirements for water, nutrients and space. So it less severe form of competition.

In climax communities every strata and every kind of plants adjust themselves to the habitat. So they become interdependent upon each other. All the plants living in a climax community do not face any competition for food, water, space and air. A dominant plant does not compete with secondary dominant one, under shrubs herbs or ground flora. Each layer and each species have different requirements for water, light, space and nutrients

5. Reaction

The effect of plants on the habitat is known as reaction. Some reactions are direct result of the plant activities. These include decrease of water by absorption and increase in humidity due to transpiration. There is a death and decay of plants or plant organs. It adds organic matter into the soil. Therefore, the physical and chemical properties of the soil are changed. Thus soil fertility is increased and water holding capacity of the soil is improved.

6. Stabilization

Many reactions have taken place in the community and habitat. Now a time has come that no reactions are possible. Therefore, now the habitat can not be modified further. At this stage, a stable and complex community is formed. It becomes more or less permanent and stabilized. Now this community is fully developed, stable, self perpetuating. It is in equilibrium with the climate. This type of community is known as **Climax Community**.

The climax is thus a product climatic factor.

XEROSERE (Succession in dry conditions)

The succession occur in dry condition is called Xerosere. It undergoes following stages.

1. Crustose lichen stage

Thallus like structure

Crustose are land lifeless structure. It is a bare rock. It consists of solid surface or very large boulders. It has no place for penetration of roots of plants. The crustose may have an external protective layer surface on the rock. Special types of lichens can grow on these rocks. The lichens are called **crustose lichens.** Its most common species are *Rhizocorpon, Rinodina and Lecanora.* Air brings propagules of these lichens. Thalli of crustose lichens can adhere to the surface of rock. They absorb moisture from atmosphere and grow on this bare rock. These lichens can live in extreme conditions. Sometime, their surface becomes wet due to rain and dew-drops. They absorb water during dry season. These lichens produce acids. These acids cause weathering of the rock. These lichens then die. Their thalli are decomposed to produce humus. It prepares the land for next stage. This soil is now suitable for growth of foliose lichens.

2. Foliose and Fruticose lichen stage

Now habitat is suitable for foliage lichens. Foliose lichens are leaf like. Fruticose lichens are like small bushes. They are attached at one point only. Therefore, they do not cover the soil completely. Their examples are *Parmelia* and *Dermaticarpo.* They can absorb and retain more water. Thus they accumulate more dust particles. They produce shade on the crustose lichens. As a result, the growth of crustose lichen is reduced or decreased. They make the soil acidic. Humus is added to it. It makes the rock rough. The shallow depressions in the rocks and crevices are filled with soil. This substratum is suitable for growth of mosses.

3. Moss stage

The soil becomes more porous. Litter of the lichens is collect in it. Thus at this stage moss plants invade the area. The examples of mosses are *Polytrichum and Tortula.* The mosses compete with lichens for water. They penetrate much deeper in the soil as compared to the lichens. The lichens become dead. Thus more humus is added to the soil. Minerals combine with this humus. The bodies of mosses are rich in organic and inorganic compounds. These compounds are added to soil on their death. Mosses develop in small patches. Soil particles from air are deposited between these patches. It increases the substratum. This environment is now suitable of herbaceous plants.

4. Herbaceous (plant) stage

The soil has a large amount of humus and litter. Thus its water holding capacity is increased. Thus there is more availability of moistures, humus and soil for anchorage. The herbaceous plants are now established there. These plants increase the process of weathering. Evaporation or transpiration takes place. It reduces the temperature. Now bacteria, fungi and other animals establish there. Some xerophytes grasses also establish there.

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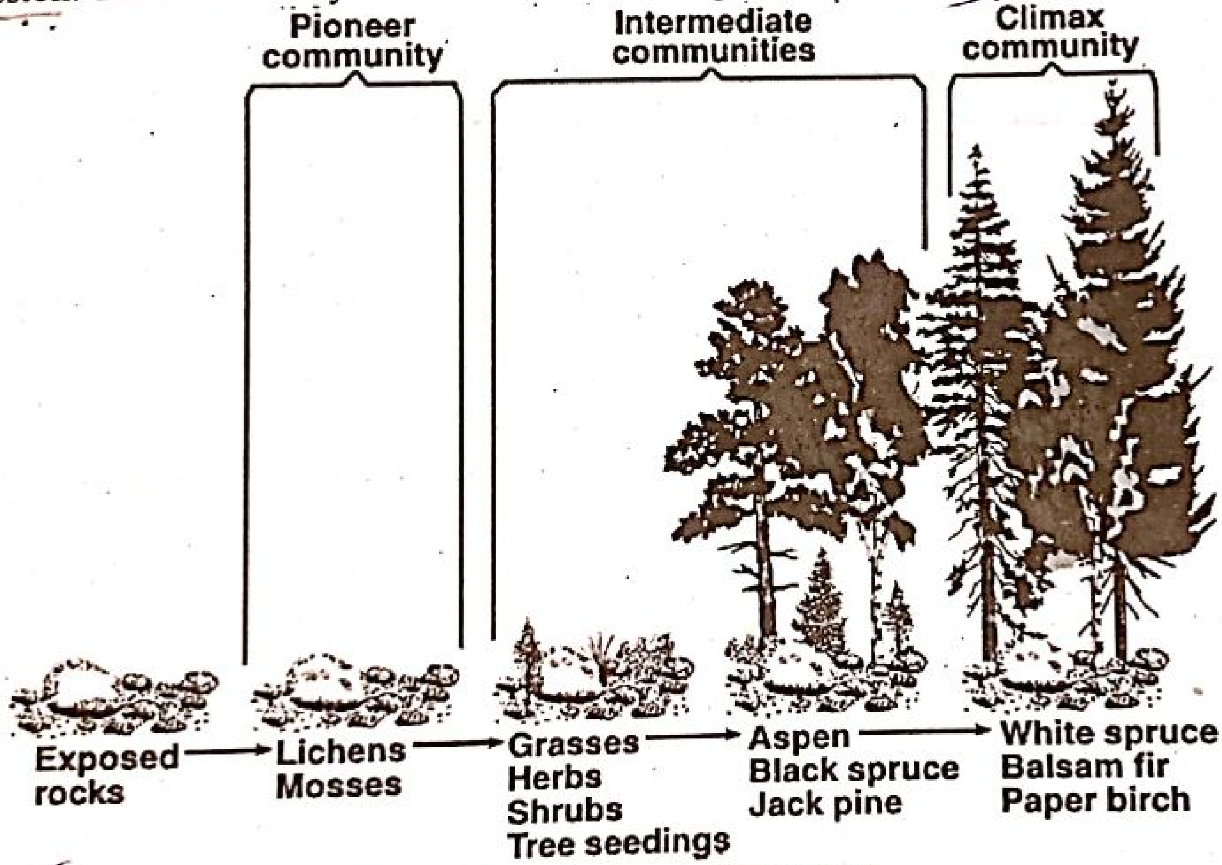
5. Shrub stage

Soil conditions are now becomes favourable for shrubs. Shrubby plants now start growing. They become dense. They cast shadow on herbs so the herbs die. Thus the herbaceous plants add more humus to the soil. The roots of shrubs penetrate into soil. They develop wide cracks in rock. The process of soil formation continues.

6. Climax stage

The soil is much improved now. So it now allows the growth and establishment of woody plants. These plants are densely rooted. The shade of these plants inhibits the growth of most plants. Woody plants dominate in this stage. This stage essentially remains the same if nothing changes in the environment to upset the balance. It is a stable stage in succession. Thus the woody forest is the climax stage for this region.



✓ Fig: Different stage of Xerosere

(change

HYDROSERE (Succession in water bodies)

Hydrosere succession occurs in water bodies undergo. It has following stages:

1. Phytoplankton stage

Unicellular floating algal plants like diatoms are called phytoplankton. They pioneer species of a bare water body like pond. Their spores are carried by air to the pond. The phytoplankton is followed by zooplankton. They settle down to the bottom of the pond after death. They decay into humus. This humus mixes with silt and clay particles. These Runoff water and wave action and form soil bring these particles into the basin. Now soil builds up. The pond becomes shallower and further environmental changes follow it.

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1. Submerged stage

The water body has become shallower now. There is increasing light penetration in the shallower water. This is suitable for growth of rooted submerged species. Plants are entirely submerged near the bank of lake or pond. These are pioneers of the hydrosere. They include several flowering plants like *Hydrilla*, *Potamogeton* etc. Thus these plants grow at various depths. They are mostly rooted in the muddy or sandy bottom. Light can penetrate there. There are death and decay of the submerged plants. Thus material is collected at the bottom of the lake. Inorganic sediment is still entering the lake. It is trapped more quickly by the net of plant roots and rhizomes. The pond becomes shallow now. Therefore, the habitat becomes suitable for the floating species. It is now less suitable for rooted submerged plants.

2. Floating Stage

The water depth of lake becomes six to eight feet. Now it is occupied by floating plants. Floating plants are rooted in the mud. But their leaves float on the surface of the water. Some free-floating species also become associated with rooted plants. Most of these plants have rhizomes. They grow from rhizome. Some of these plants are *Nymphaea Nelumbium. Nymphoides* and *Eichornia*. *Nymphaea* and *Eichornia* have broad leaves. They cover the water surface. It cuts off light for the submerged plants. These plants migrate to deeper waters or died. Soil and dead plants accumulate in the lake. Now the habitat becomes unfit for floating plants.

3. Reed Swamp Stage

The water has become shallow. Now it has become suitable for the partly submerged plants. Their leaves are raised above the water surface. Some common plants are *Sagittaria*, *Typha*, *Sperganium*, *Polygonum* etc. These plants give shade to the surface of the water. They retain the sedimentary material. It builds up the lake banks. Thus the water depth is further decreased.

4. Sedge Meadow Stage

Roots

Now the lake has become very shallow. Thus the sedges and grasses dominate the area. Some of these are *Carex*, *Juncus*, *Scirpus* etc. They develop rhizomes and slender roots. These plants accumulate plant debris and soil. They transpire a large amount of water. Therefore, the habitat becomes dry. It becomes unsuitable for sedge meadow plants.

5. Woodland Stage

(bushy)

Now certain species of shrubs and trees appear. They can tolerate waterlogged soil conditions. Species of *Salix* and *Populus* grow there. These plants produce shade. They also lower the water table by transpiration. They also build up the soil. Thus the habitat becomes unfavourable for the woodland stage.

6. Climax Stage

(grass)

Now soil is enriched with minerals. The water table has also gone down. These conditions are favourable for other plants. Hydrophytes are replaced by mesophytes. Ultimately a stable community (climax) is formed. It is primarily controlled by climatic conditions. This stage is dominated by annual trees.

Finally a self-perpetuating climax community develops. It may be a forest if the climate is humid. It may be grassland in case of sub-humid environment. Or it may be a desert in arid and semi-arid conditions. A forest is characterized by presence of all types of vegetation. These include herbs, shrubs, mosses, shade-loving plants and trees. Decomposers are frequent in climax vegetation.

7. Formation of a community

The overall changes taking place during development of successional communities. These changes include building up of substratum, shallowing of water, addition of humus and minerals, soil building and aeration of soil. The water body fills in with sediment. Now the area of open water decreases. The vegetation types moves inwards as the water becomes shallower. Many of the such communities can be seen growing together in a water body. The center is occupied by floating and submerged plants with reeds nearer the shores. It is followed by sedges and rushes growing at the edges. Still further are shrubs and trees. They occupy the dry land.

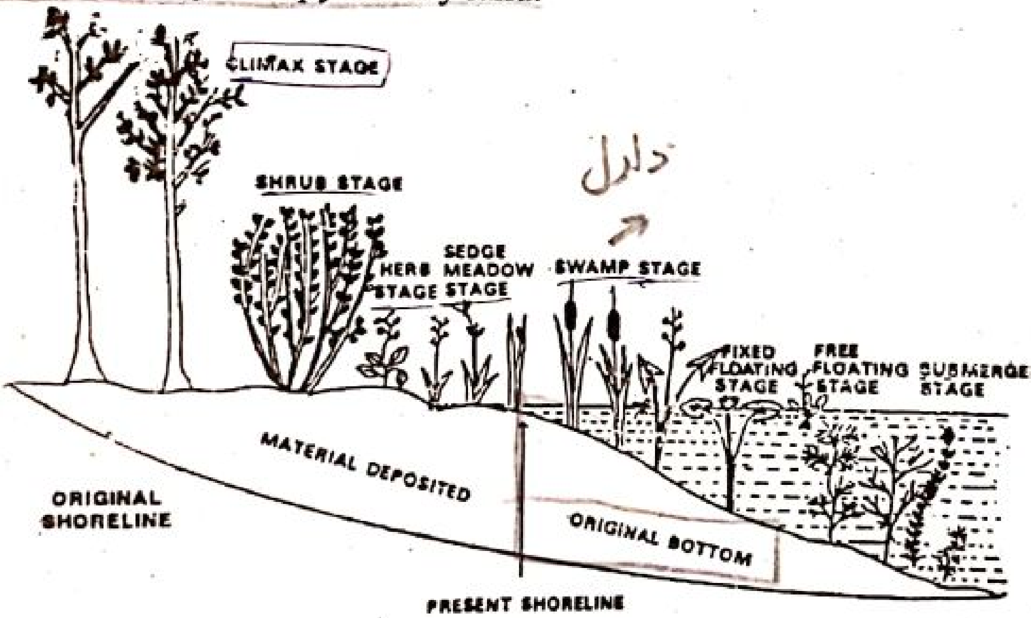


Fig: Different stage of hydrosere

THEORIES OF SUCCESSION

Concept of climax community in succession

[illegible]

Climax community (only Def:)

The final or stable community in a sere is called climax community. It is self-perpetuating. It is in equilibrium with the physical habitat. There is no net annual accumulation of organic matter in a climax community. The annual production and use of energy is balanced in such a community.

Characteristics ✓

1. The vegetation is tolerant of environmental conditions.
2. It has a wide diversity of species.
3. It has a well-drained spatial structure.

4. It has complex food chains.
5. The climax ecosystem is balanced. There is equilibrium between gross primary production and total respiration. There is balance between energy used from sunlight and energy released by decomposition. There is balance between uptake of nutrients from soil and return of nutrient by litter fall to soil.
6. Individuals in climax stage are replaced by others of the same kind. Thus the species composition maintains equilibrium.
7. It is an index of the climate of the area. The life or growth forms indicate the climatic type.

Types of climax

There are followings types of climax:

1. Climatic Climax

In climatic climax, there is only a single climax and the development of climax community is controlled by the climate of the region. For example, development of Maple-beech climax community over moist soil. Climatic climax is theoretical. It develops where physical conditions of the substrate are not much extreme. These conditions can modify the effects of regional climate.

2. Edaphic Climax

In edaphic climax, there are more than one climax communities in the region. It is modified by local conditions of the substrate. These conditions are like soil moisture, soil nutrients, topography, slope exposure, fire and animal activity.

3. Catastrophic Climax

Climax vegetation can be attacked by catastrophic event like wildfire. A rapid development of herbaceous vegetation follows it. The shrub dominance is re-established. This is known as catastrophic climax.

4. Disclimax

In disclimax case, a stable community is maintained by man or his domestic animals. For example, overgrazing by stock may produce a desert community. It grows bushes and cacti. The local climate actually is of grassland.

5. Subclimax

The prolonged stage in succession just preceding the climatic climax is sub-climax.

6. Preclimax and Postclimax

In certain areas, different climax communities develop under similar climatic conditions.

- A preclimax community has life forms lower than expected climatic climax.
- A postclimax community has life forms higher than those in the expected climatic climax.

Theories of Succession Def only

There are three theories of succession about climax communities:

1. Monoclimax theory

This theory was put forward by an American ecologist **Frederick Clements** in 1916. According to this theory there is only one climax community in a climatic or geographical region. But topographic differences and different soil types form other communities in the same zone. These communities are known as **subordinate communities**. The subordinate communities may be proclimax, postclimax, disclimax, preclimax, and subclimax communities.

(a) **Proclimax:** The community which is more or less stable resembling the climax community is called proclimax.

(b) **Disclimax:** The community disturbed by man or other animals is called disclimax community. Its example is grassland in forest area.

(c) **Subclimax or preclimax:** The community in which development is stopped in the subfinal stage of succession due to burning, cutting or grazing and flooding is called subclimax or preclimax community.

(d) **Post climax:** The community in which a strip of vegetation of higher life form is found within a climax is called post climax community. Its example is forest strip along a stream in grassland.

2) Polyclimax Theory Def

This theory was put forward by European ecologists **Nicholos, Champion** and **Whitaxer** in1953. According to this theory a number of different climax communities are present in climatic or geographical region. Thus preclimax, postclimax and disclimax communities are all climax communities. They are all self-reproducing communities. They can maintain themselves for an indefinite period of time. This theory does not rule out climax communities. But it gives other stages of communities as full status of climax communities. Thus these are not regarded as minor communities

3) Climax Pattern Theory Def

This theory was put forward by **Whitaker** (1963), **Mcintosh** (1958) and **Sellech** (1913). According to this theory the structure, composition and other characters of the climax communities are determined by the total environment of the ecosystem. It is not determined by single factor. Climax community is composed of animal communities. These communities have close interrelationship with the flora and fauna of the area, soil and climate. A particular plant cannot survive. Its seeds must be properly distributed. Similarly an animal cannot survive without food of plants. The climatic climax is the most popular community. **The community which expresses the climate of the area is called cilmatric community.**

CONCEPT OF PRODUCTIVITY ✓

The rate at which food is manufactured by the producers in unit area in unit time is called productivity. There are following types of productivity:

1. Primary Productivity

The rate at which solar energy is converted into organic energy by green plants or total food assimilation rate of producers is called primary productivity. Primary productivity can be measured in grams of carbohydrate produced per unit of land surface per year. Primary productivity is of two types (e.g) tot. no. of individual – not present = net

(a) **Gross primary productivity: The total rate of photosynthesis or the total amount of organic matter fixed is called gross primary productivity.** It also includes the organic matter used up in plant respiration.

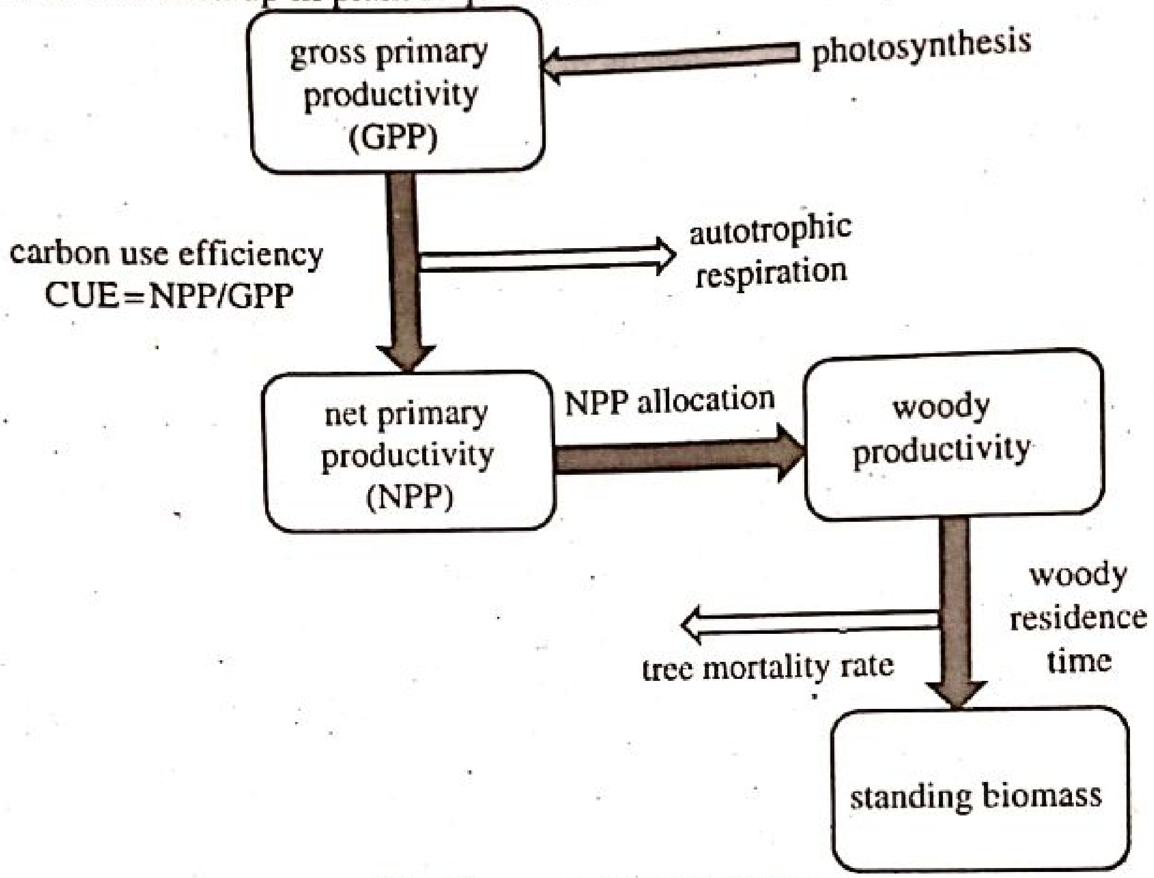


Fig: Concept of productivity

(b) **Net primary productivity: The organic matter stored in plant tissues is called net primary productivity.** The organic matter used up in the process of respiration is excluded from it. It is the food available to the consumers.

Plants ⇓ Hetro/consum

Relationship between the two types of productivity may well be understood by the following simple equations

Gross primary productivity = Photosynthesis + Respiration

Net primary productivity = Gross primary productivity—Respiration

2. **Secondary productivity**

The amount of energy available to other trophic level i.e. the heterotrophs or the consumers is called secondary Productivity.

(Pak. veg. book) Net.

LOCAL VEGETATION OF PAKISTAN

The vegetation in Pakistan is divided into five categories on the basis of climate, altitude and plant types. These are:

1. Dry tropical forest vegetation veg. xerophytes + sandy.ka[illegible] 6-12 inch +
2. Dry sub-tropical sub-mountainous vegetation Tree + shrub + 10-36 inch + 40°C [H- 50%]
3. Dry Temperate forests vegetation (xerophytes) + (30 inches) + (Low than 0°C) [cold winter + snow]
4. Moist temperature forest vegetation (coniferous trees) + (30-60 inch ↓ (monsoon)) + (-25-30°C) [snow 15 ft.]

xerophytes + [Deep snow + cold wind] + [4-26 inch] + [50°F]

5. Sub –Alpine and Alpine vegetation

1. Dry Tropical Forest Vegetation

Greater part of Pakistan has tropical conditions. The dry tropical forests are distributed in the tropical coastal area, Indus plan, and Low hills of Baluchistan and Sind. Their vegetation chiefly consists of xerophytes. Biotic communities are developed on large tract of land. This land is used for agriculture. Dry tropical forests are classified as follows:

(a) **Dry Tropical Thorn Forest Vegetation (Indus plain and hills):** They are distributed in Indus basin plains of Punjab, Sind, and coastal region of Pakistan. The hills are scattered throughout the Indus plain. Some of plants *are Prosopis juliflora. Prosopis cineraria Acacia nilotica* (kikar) and *Acacia senegal*.

(b) **Vegetation of Riverian Tract and Indus Delta:** The area present around the river is called riverain tract. Some of plants found in this area are *Saccharum munja* (sarkanda), *Tamrix indica* etc. The tract where rive enters into sea is called delta. The delta has forests of mangroves.

(c) **Vegetation of Sandy Tracts:** Sandy tract includes Thal, Cholistan and coastal tract of Makran and Sind. The average rain fall in these regions is 6 -12 inches. Some of the plants in these regions are *Salvadora*, *Acacia* and *Euphorbia*. Lowest Rain

(d) **Vegetation of Irrigated Plantation:** Canal system is developed in the Indus basin region of Pakistan. This area was included in Tropical rain forests. These forests have been cleared and its land is used for agriculture.

2. Dry sub-tropical sub-mountainous vegetation

This vegetation includes trees and shrubs. The trees may show dense growth. The trees and shrubs are thorny. The average rain fall in this region is 10 – 36 inches. Humidity is low. The annual mean humidity is 50%. Temperature rises to 40°C in summer. This area includes Siwalik Hills and Baluchistan Plateau.

(a) **Vegetation of Siwalik Hills:** Siwalik Hills include Potohar plateau, salt range and hills of the NWFP. Some of plants found in this regions are *Acacia modesta*, *Olea cuspidate*, *Dalbergia sisso* etc. → اونٹ

(b) **Vegetation of Baluchistan Plateau:** This area is distributed in dry hills, sand dunes and coastal low hills of Baluchistan. They have xerophytic plants. The plants found in these areas are *Juniperous*, *Mentha*, *Tamarix* etc.

3. Dry Temperate forests

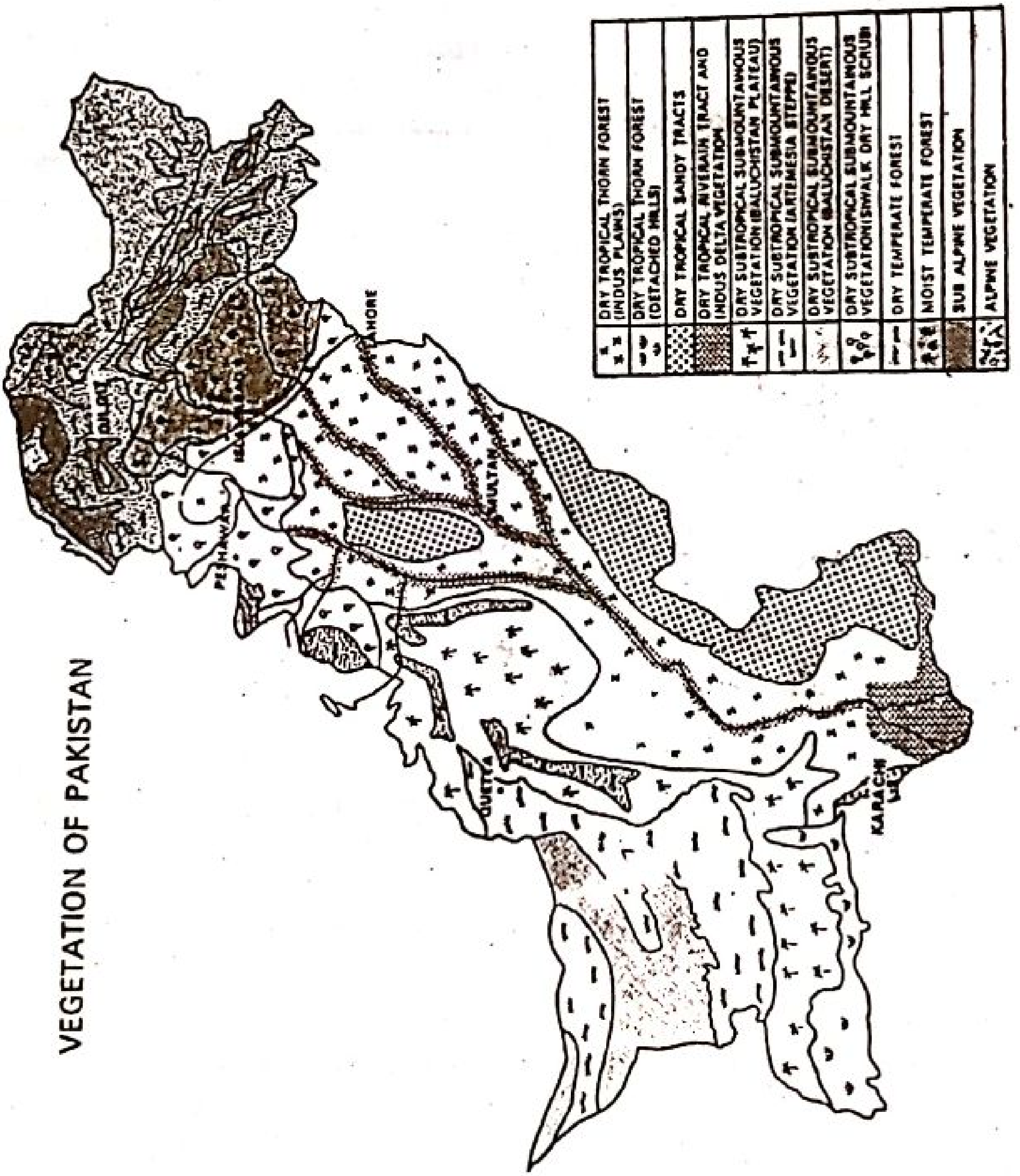
They have unfavourable climate. Thus they have less number of plants. Most of this area has bare soil. Here plants are mostly Xerophytic. This region includes Suleiman Range, Koh Safad Range, Koh Hindu Kush Range, Karakoram Range and lower part of the Neelam valley (Azad Kashmir). This region has long cold winter. Temperature becomes lower than zero. The annual total rain fall is less than 30 inches. Some of these areas are covered by snow. Thus most of this area is a zone of winter rain and snow. Some of the genera found in this region are *Juniperous, Fraxinus, Prunus, Stipa, Dodonoea, Fragraria, Pinus, Ephedra* and *Rumex*.

4. Moist Temperate Forest مُعتدلہ مرطوب / سیروالے

These are found along the Himalayan Mountains. They are located in Kashmir, Murree – Hazara hill tract, Swat, Dir, Gilgit and Baltistan districts.

These mountains receive heavy monsoon rain fall during July to September. Annual rain fall is 30 to 60 inches. Most of precipitation takes place in the form of snow. Snow fall may reaches up to 15 feet. The melting of snow provides adequate moisture. Average humidity is 57%. Temperature ranges between -25 to 30°C.

These are coniferous forest. They contain coniferous plants like *Pinus roxburghii, Pinus wallichiana, Texus wallichiana, Abies pindrow, Cedrus deodara* etc. Some broad leave plants are also present there. These are apple, Almond, Apricot etc.


DRY TROPICAL THORN FOREST (INDUS PLAINS)
DRY TROPICAL THORN FOREST (DETACHED HILLS)
DRY TROPICAL SANDY TRACTS
DRY TROPICAL RIVERAIN TRACT AND INDUS DELTA VEGETATION
DRY SUBTROPICAL SUBMOUNTAINOUS VEGETATION (BALUCHISTAN PLATEAU)
DRY SUBTROPICAL SUBMOUNTAINOUS VEGETATION (ARTEMESIA STEPPE)
DRY SUBTROPICAL SUBMOUNTAINOUS VEGETATION (BALUCHISTAN DESERT)
DRY SUBTROPICAL SUBMOUNTAINOUS VEGETATION (SIWALIK DRY HILL SCRUB)
DRY TEMPERATE FOREST
MOIST TEMPERATE FOREST
SUB ALPINE VEGETATION
ALPINE VEGETATION
LAHORE
MULTAN
PESHAWAR
QUETTA
KARACHI

VEGETATION OF PAKISTAN

There is heavy grazing and trampling in these forests. Therefore, most of the moist forests have been destroyed. These forests are replaced by small grasses, some legumes and some members of Liliaceae. These flat grassy grounds are called **parklands**. They are mostly found in Murree, Kaghan valley and upper Swat.

5. Sub alpine and Alpine vegetation (بیر والے خشک درخت) → گرم

The vegetation zone above the moist temperate coniferous forest is called sub-alpine and alpine region. It is found in Himalayan Mountains of Kaghan, Swat, Baltistan, Gilgit Agency, Chitral, Dir and Kurram Agency.

The growing season is short in these zones. They had deep snow and cold wind. So they have xerophytic habitat for plants. These zones are away from the monsoon region. Therefore, annual rain fall is very low. Thus rain fall ranges between 4 – 26 inches. Maximum temperature is 50°F.

Betula utilis is characteristic and dominant specie of sub-alpine region. It attains height of 20 feet. Some other deciduous tree genera are *Sorbus* and *Salix*. Alpine vegetation is composed of deciduous and small leaved species. Growing period is shorter. Most common plants found in alpine zone are genera of *Arenaria, Salix, Berberis* etc.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Community	The populations of different species living in the same habitat is called community.
Analytic characteristics	The characteristics which can be analyzed by quantitative or qualitative methods are called analytic characteristics.
Qualitative characteristics	The disruptive characteristics which cannot be measured are called qualitative characteristics.
Stratification	The plants occurring together with a similar ecology in definite strata are called stratification
Periodicity	The rhythmic phenomena related to seasonal changes is called periodicity.
Vitality	The capacity of plants to complete its life cycle is called vitality.
Quantitative characteristics	The characteristics which can be measured are called quantitative characteristics.
Density	The number of individuals of specie in a unit area is called density.
Abundance	The estimation of individuals of specie is called abundance.
Fidelity	The relative occurrence of specie in an association or a group of related association is called fidelity.

Physiognomic characteristics	The general appearance or outlines of the stand or community are called physiognomic characteristics.
Phanerophytes	These plants include woody trees and shrubs. Their bud bearing shoots are elevated and exposed to the atmosphere.
Therophytes	It includes all the annual plants. Their only perennating buds are present in seeds.
Chamaeophytes	They include wood or semi woody perennial under shrubs. The bud is above the ground but less than 25 cm high. Example Salvia sp.
Hemi-cryptophytes	The perennating buds are half hidden in the surface of soil. Example euphorbia.
Cryptophytes	Their buds are in soil or under water, e.g. Hydrilla.
Transect	A transect is a long rectangular sample plot.
Quadrat	A quadrat is a sampling unit used for the quantitative study of plant communities.
Succession	The process of community development is called succession.
Primary succession	The formation of ecosystem from bare rock, sand or clear glacial pool where previous life do not exist is called primary succession.
Autogenic succession	The succession in which organisms themselves bring change in the environment during succession is called autogenic succession.
Allogenic succession	The succession in which external environmental factors cause change in the environment during succession is called allogenic succession.
Ecesis	The phenomena of growth of propagules and their adjustments in the new surrounding area is called ecesis.
Competition	The struggle for existence between the plants is called competition.
Reaction	The effect of plants on the habitat is known as reaction.
Proclimax	The community which is more or less stable resembling the climax community is called proclimax.
Productivity	The rate at which food is manufactured by the producers in unit area in unit time is called productivity.
Primary productivity	The rate at which solar energy is converted into organic energy by green plants or total food assimilation rate of producers is called primary productivity.

MODEL SUBJECTIVE QUESTIONS

1. **Give attributes of plant communities.**
2. **Give physiognomic characteristics.**
3. **Describe different sampling methods.**
4. **What is succession? Give its types.**

5. **Describe different stages of Xerosere.**
6. **Describe different stages of Hydrosere.**
7. **Describe different theories of climax.**
8. **Write note on productivity.**
9. **Describe local vegetation of Pakistan**

SHORT QUESTIONS

1. What is community?

Ans: **The populations of different species living in the same habitat is called community.** According to Oosting (1956), plant community is an aggregation of individuals with mutual relationships among themselves and to their environments.

2. What are analytic characteristics?

Ans: The characteristics which can be analyzed by quantitative or qualitative methods are called analytic characteristics.

3. What is stratification?

Ans: The plants occurring together with a similar ecology in definite strata are called stratification.

4. What is periodicity?

Ans: **The rhythmic phenomena related to seasonal changes is called periodicity.** These changes are growth, flowering, pollination, ripening of fruit and seed. Periodicity is controlled by different environmental factors like light, temperature etc.

5. What are synthetic characteristics?

Ans: **The generalization and integration of characteristics that derived from data of analytic qualities are called synthetic characteristics.** In this case, data is arranged in tubular form. Then synthetic characteristics are studied.

6. What are physiognomic characteristics?

Ans: The general appearance or outlines of the stand or community are called physiognomic characteristics.

7. What are Phanerophytes? Give examples. These plants include woody trees and shrubs. Their bud bearing shoots are elevated and exposed to the atmosphere. Example, Acacia sp.

8. What is transect? Give its uses.

Ans: **A transect is a long rectangular sample plot.** It is used to study variations in vegetation. Vegetation varies with the changing environments. These variations are caused by slope, exposure, edaphic and topographical irregularities.

9. What is a quadrate? Give its uses.

Ans: **A quadrat is a sampling unit used for the quantitative study of plant communities.** It may be a square, rectangular or circular in shape. But rectangular plots are more useful. A quadrat can have any size. But generally, large quadrat is used for richer and heterogenous plant community.

10. What is primary succession?

Ans: The formation of ecosystem from bare rock, sand or clear glacial pool where previous life does not exist is called primary succession. In this case, the ecosystem is formed from the start. So it is a long process.

11. What Xerophytes and succulent plants?

Ans: Plants growing in xeric condition are called **xerophytes**. Xerophytes can withstand prolonged periods of water shortage. Water is stored in large parenchyma tissue in **succulent** plants like cacti.

12. What is simple and mixed aggregation?

Ans: The grouping and growing of offspring around the parent plant is called **simple aggregation**. The gradual spreading and mixing of the neighbouring plants is called **mixed aggregation.**

13. What is Monoclimax theory?

Ans: According to this theory there is only one climax community in a climatic or geographical region. But topographic differences and different soil types form other communities in the same zone. These communities are known as **subordinate communities.**

14. What is Polyclimax theory?

Ans: This theory was put forward by European ecologists **Nicholos, Champion** and **Whitaxer** in1953. According to this theory a number of different climax communities are present in climatic or geographical region. Thus preclimax, postclimax and disclimax communities are all climax communities.

15. Differentiate between primary and secondary productivity.

Ans: The rate at which solar energy is converted into organic energy by green plants or total food assimilation rate of producers is called primary productivity. The amount of energy available to other trophic levels i.e. the heterotrophs or the consumers are called secondary Productivity.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. The plants occurring together with a similar ecology in definite strata are called:
(a) Periodicity (b) stratification (c) Floristic (d) Vitality

2. The rhythmic phenomena related to seasonal changes is called periodicity.
(a) Periodicity (b) stratification (c) Floristic (d) Vitality

3. The capacity of plants to complete its life cycle is called:
(a)stratification (b) Periodicity (c) Floristic (d) Vitality

4. The number of individuals of specie in a unit area is called:
(a) Abundance (b) Density (c) Frequency (d) Cover

5. The estimation of individuals of specie is called:
(a) Abundance (b) Density (c) Frequency (d) Cover

6. The degree of occurrence of individuals of a species within an area is called:
(a) Frequency (b) Cover (c) Abundance (d) Density

7. The relative occurrence of specie in an association or a group of related association is:
(a) Fidelity (b) Dominance (c) Constancy (d) Presence

8. A specie that occurs in 90% or more of the stand is:
(a) Fidelity (b) Dominance (c) Constancy (d) Presence

9. The species which have high number and large volume are:
(a) Dominance (b) Fidelity (c) Constancy (d) Presence

10. Which of the followings is cryptophytes?

(a) Cotton (b) Euphorbia (c) Acacia (d) Hydrilla

11. Which of the followings is Phanerophytes?

(a) Cotton (b) Euphorbia (c) Acacia (d) Hydrilla

12. Which of the followings is Hemi-cryptophytes?

(a) Cotton (b) Euphorbia (c) Acacia (d) Hydrilla

13. The sampling unit used for the quantitative study of plant communities:

(a) Transect (b) Strip (c) Quadrat (d) None

14. A long rectangular sample plot is:

(a) Transect (b) Strip (c) Quadrat (d) None

15. Primary succession occurs in a pond is:

(a) Hydrosere (b) Psammosre (c) Halosere (d) Xerosere

16. The succession which occurs on sand dunes is called:

(a) Hydrosere (b) Psammosre (c) Halosere (d) Xerosere

17. The succession occurs on dry habitat is called:

(a) Psammosre (b) Hydrosere (c) Halosere (d) Xerosere

18. The succession occurs on a dry soil or rock is:

(a) Hydrosere (b) Psammosre (c) Halosere (d) Derosere

19. The effect of plants on the habitat is known:

(a) Reaction (b) Aggregation (c) Competition (d) Ecesis

20. Phenomena of growth of propagules and their adjustments in new surrounding:

(a) Reaction (b) Aggregation (c) Competition (d) Ecesis

Answers 1. (b) 2. (a) 3. (d) 4. (b) 5. (a) 6. (a) 7. (a) 8. (c) 9. (a) 10. (d) 11. (c) 12. (b) 13. (c) 14. (a) 15. (a) 16. (b) 17. (d) 18.(d) 19. (a) 20. (d)

Fill in blanks

1. The populations of different species living in the same habitat is called __________.
2. Characteristics analyzed by quantitative or qualitative methods are ______ characteristics.
3. Disruptive characteristics which cannot be measured are called __________ characteristics.
4. The plants occurring together with a similar ecology in definite strata are called __________.
5. The rhythmic phenomena related to seasonal changes is called __________.
6. The capacity of plants to complete its life cycle is called ____.
7. The number of individuals of specie in a unit area is called ________.
8. The estimation of individuals of a specie is called ________.
9. The degree of occurrence of individuals of a species within an area is called ________.
10. A specie that occurs in 90% or more of the stand is called _______ constant.
11. The species which have high number and large volume are called _____________ species.
12. General appearance or outlines of stand or community are called _________ characteristics.
13. A _________ is a long rectangular sample plot.
14. A _________ is a sampling unit used for the quantitative study of plant communities.
15. The process of community development is called ________.
16. Phenomena of growth of propagules and their adjustments in new surrounding area is _____.
17. The capacity of plants to complete its life cycle is called ______.
18. The degree of aggregation of plants in nature is called ______.
19. The appearance of stand is called ______.
20. A ______ is a long rectangular sample plot.
21. ______ Transect is also called as line intercept method.

22. Succession ends with a diverse and relatively stable ______ community.
23. A community with population of different species remain ______ is climax community.
24. The process of community development is called ______.
25. Phenomena of growth of propagules and their adjustments in new surrounding area is ______.
26. The struggle for existence between the plants is called ______.
27. In ______ case, a stable community is maintained by man or his domestic animals.
28. The prolonged stage in succession just preceding the climatic climax is ______.
29. The community which expresses the climate of the area is called ______ community.
30. The flat grassy grounds are called ______.
31. Vegetation zone above moist temperate coniferous forest is called sub-alpine and ______.

An: 1. Community, 2. analytic , 3. Qualitative, 4. Stratification, 5. periodicity, 6. Vitality, 7. Density. 8. Abundance, 9. Frequency, 10. Specie, 11. Dominant, 12. Physiognomic, 13. Transect, 14. Quadrat, 15. Succession, 16. ecesis 17. Vitality, 18. Sociability, 19. Physiognomy, 20. Transect. 21. Line. 22. Climax, 23. Uniform. 24. Succession. 25. Ecesis. 26. Competition, 27. Disclimax, 28. sub-climax, 29. Cilmatric, 30. Parklands, 31. alpine

True/False

1. The populations of different species living in the same habitat are called community.
2. The disruptive characteristics which cannot be measured are called qualitative characteristics.
3. A complete list of species is called soil composition.
4. The plants occurring together with a similar ecology in definite strata are called stratification.
5. The rhythmic phenomena related to seasonal changes is called periodicity.
6. The capacity of plants to complete its life cycle is called sociability.
7. The degree of aggregation of plants in nature is called sociability.
8. The characteristics which can be measured are called quantitative characteristics
9. Relative occurrence of specie in an association or a group of related association is sociability.
10. The appearance of stand is called physiognomy.
11. A quadrat is a long rectangular sample plot.
12. Line Transect is also called as line intercept method.
13. A quadrat is a sampling unit used for the quantitative study of plant communities.
14. The process of community development is called population.
15. Each succession begins by a few hardy invaders called pioneers.
16. Succession ends with a diverse and relatively stable climax community.
17. A community with population of different species remain uniform is simple community.
18. The process of community development is called succession.
19. Phenomena of growth of propagules and their adjustments in new surrounding area is ecesis.
20. The struggle for existence between the plants is called community.
21. In disclimax case, a stable community is maintained by man or his domestic animals.
22. The prolonged stage in succession just preceding the climatic climax is sub-climax.
23. The community which expresses the climate of the area is called climax community.
24. The flat grassy grounds are called parklands.
25. Vegetation zone above moist temperate coniferous forest is called sub-alpine and alpine.

Ans: 1. T, 2. T, 3. F. floristic, 4. T, 5. T, 6. F. vitality, 7. T, 8. T, 9. F. fidelity, 10. T, 11. F. transect, 12. T, 13. T, 14. F. succession, 15. T, 16. T, 17. F. climax, 18.T, 19. T, 20. F. competition, 21. T, 22. T, 24. F. cilmatric, 25. T

Chapter 6

ECOSYSTEM

Syllabus

1. Definition and background
2. Ecological energetic
3. Biogeochemical cycle (Hydrologic and nitrogen cycle)

ECOSYSTEM

A community with its non-living environment is called ecosystem. Odum, E.P. (1959) defines ecosystem as "an area of nature, that includes living organism and nonliving substances, interacting to produce an exchange of materials between the living and nonliving parts. Non-living environment provides energy raw materials and space to the living organism. They use these materials for their growth and development.

Component of Ecosystem

An ecosystem is composed of abiotic (nonliving) and biotic (living) components:

(A) Abiotic component

Abiotic component include basic elements and compounds of the environment like soil, water, gases. It is also composed of minerals like carbonates, phosphates etc. It also has variety of organic compounds. It also includes physical factors like moisture, wind, currents and solar radiation. Solar energy is the source of energy for the entire ecosystem.

(B) Biotic components

The living components of the ecosystem are called biotic components. There are further divided into two main parts. i.e. Autotrophs or Producers and Heterotrophs or Consumers.

(a) **Autotrophs or producers:** They are able to fix light energy and manufacture food from simple inorganic substances. They mainly consist of green plants. Some floating microscopic photosynthetic organisms are also present. They are called **phytoplanktons.**

(b) **Heterotrophs or Consumers:** They are the living organisms that utilize or decompose the complex material synthesized by the producers. The heterotrophs do not produce their own food. They depend on other autotrophic organisms for their nourishment. The heterotrophic component includes macroconsumers and microconsumers or decomposers. Macroconsumers include large animals. It is further divided into:

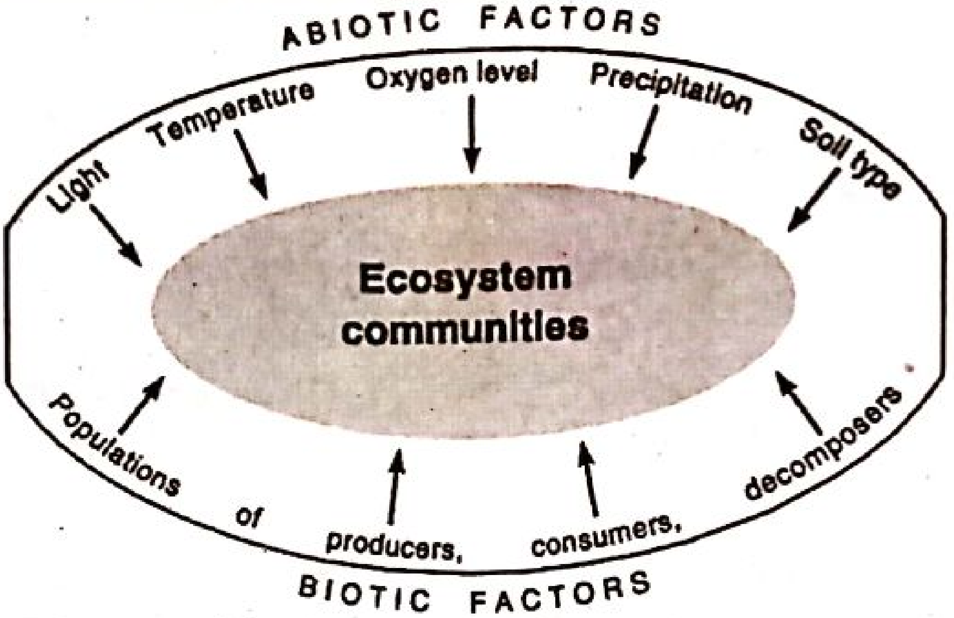


Fig: Components of ecosystem

1. **Primary consumers:** They are purely herbivorous animals. They include large animals or macroconsumers like many insects, mouse, rabbits, goat sheep, deer, birds etc. These are the common herbivorous of terrestrial ecosystem. Protozoa small molluscs and Crustaceans and fishes are herbivores of the aquatic ecosystem. It includes rotifers, protozoans and crustaceans. They live only on phytoplankton or microscopic plants.
2. **Secondary Consumers:** It includes carnivores and omnivores. **Carnivores** are the flesh eating animals. The get their energy by eating herbivores. Carnivores include some insects and other large animals like cats, dogs, snakes, fox, eagle etc. Some organism can derive their energy from both plants and animals. They are known as **omnivores**. Ants, crow, sparrow, hen, bear and man are omnivores.
3. **Tertiary Consumers: or top consumers:** They eat the herbivores, carnivores and omnivores for their energy. Tertiary consumers1include lion, tiger, hawk etc.

(c) **Decomposers: The microorganisms which decompose the bodies of dead animals and plants are called decomposes.** They are chiefly bacteria and fungi. They breakdown the complex component and protoplasm. They absorb some of the decomposed product and release minerals back into the ecosystem. These minerals once again become available to the producers. The dead material will accumulate without the decomposers. Thus the decomposers play a very important role in recycling of compounds in the ecosystem.

Types of Ecosystem

Ecosystems are divided into the following categories.

(a) Natural Ecosystems

These are undisturbed ecosystem. They can further be divided as follows:

1. **Aquatic-ecosystem:** These are composed of open water. They includes:

(a) **Marine Ecosystem:** They consists of deep water bodies, like oceans, estuaries etc.

(b) **Fresh Water Ecosystem:** They consists of lotic or running fresh water; like stream or rivers, and lentic-standing water like pond, lake etc.

2. **Terrestrial Ecosystem:** They include forest grassland, desert etc.
3. **Artificial Ecosystems:** In these types of Ecosystem, natural balance is disturbed by man and balance is maintained by him. Artificial ecosystem consists of manmade forest, orchards, cultivated fields etc.

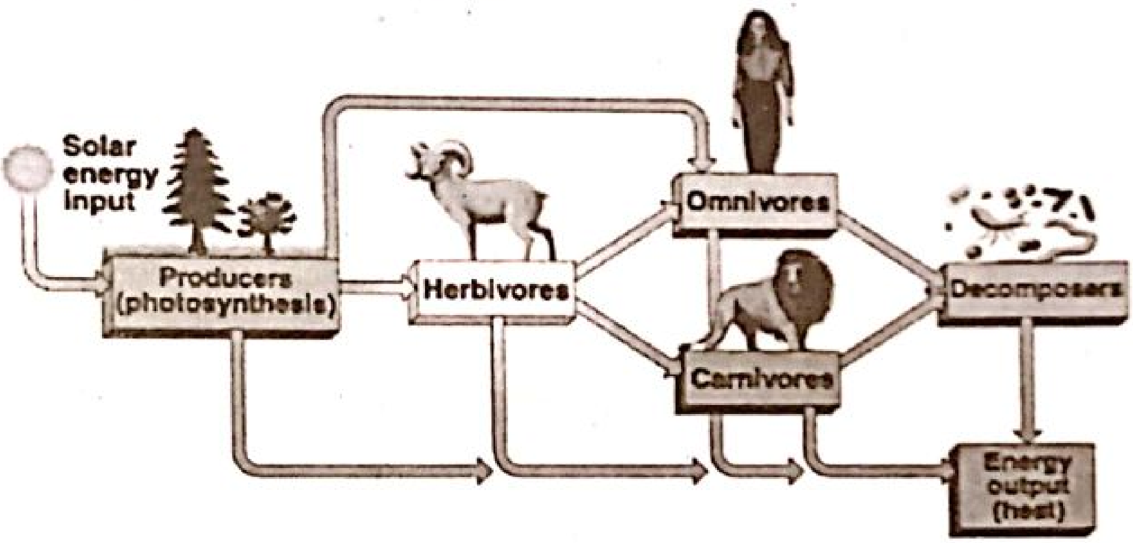


Fig: Energy flow chart

ECOLOGICAL ENERGETIC

The flow of energy through an ecosystem is called ecological energetic. Energy is the ability to do some work. The sun emits light and other types of radiation. Some of these radiations fall on the earth. The light radiation falls on some object. The object absorbs light and become warm. Thus light energy is transferred into heat energy. Land and oceans absorb heat. It produces heat and cold areas on the earth. It causes flow of air and clouds.

The source of energy on the earth is the sun. A small amount of the radiant energy is absorbed by the green plants. They change this energy into chemical energy in the form of glucose. All the other living organisms obtain this chemical energy from the plants. A large amount of energy is lost in the form of heat.

Only a small part of the solar radiation is used during photosynthesis. This stored energy provides energy to living components of the ecosystem. Green plants absorb blue and red part of the spectrum. However, only 1 to 5% of the absorbed energy is converted into food energy. The energy used once by an organism is soon lost in the form of heat. There is always one way flow of energy. The flow of energy through ecosystem follows laws of thermodynamics.

It has been estimated that about 57% of the solar energy is absorbed in atmosphere. It is scattered in space. About 36% is absorbed by water or land. About 8% falls on plants. 80

to 85% is absorbed by green plants and rest of it is reflected. About 50% of the absorbed energy is used in photosynthesis i.e. it is stored in the form of potential energy of organic compounds of green plants.

The bioenergetics is discuss under three headings:

(a) Productivity of ecosystem
(b) Food chain, Trophic levels and food web and
(c) Ecological pyramids

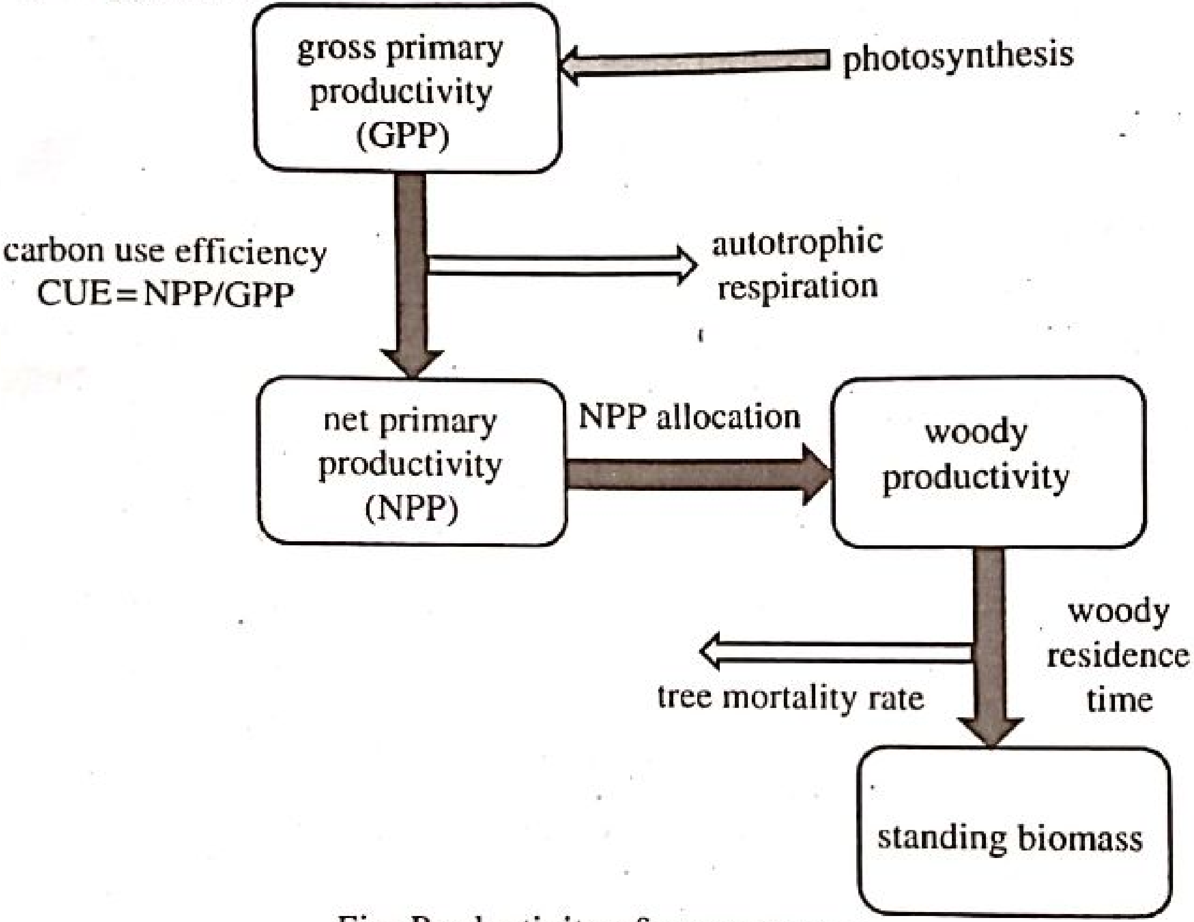


Fig: Productivity of an ecosystem

(A) PRODUCTIVITY OF AN ECOSYSTEM

The rate at which food is manufactured by the producers in unit area and in unit time is called productivity. There are following types of productivity:

1. Primary Productivity

The rate at which solar energy is converted into organic energy by green plants or total food assimilation rate of producers is called primary productivity. Primary productivity can be measured in grams of carbohydrate produced per unit of land surface per year. Primary productivity is of two types

(a) **Gross primary productivity: The total rate of photosynthesis or the total amount of organic matter fixed is called gross primary productivity.** It also includes the organic matter used up in plant respiration.

humid area. Such crops and trees should be planted in these areas.

Drought tolerant plants use o C_4 carbon fixation or crassulacean acid metabolism (CAM) to fix carbon during photosynthesis. Both are improvements over the more common but more basal C_3 pathway. C_4 plants are more energy efficient. CAM Plant are particularly good for arid conditions. They can take up carbon dioxide. Thus stomata remain closed during the heat of day. It reduces the water loss by transpiration. Succulent plants have water storage organs. They are also suitable for arid land.

6. **Crop rotation:** Crops should be rotated continuously. The variation in requirement of water by different crops can keep balance in the soil.
7. **Addition of organic matter:** Natural manure and litter can increase organic contents of the soil. Organic contents have great water holding capacity. So they reduce the aridity.

BIODIVERSITY

The variety of living organisms in an ecosystem is called biodiversity. The exact number of species in the world is not known. The taxonomists have described about 1.4 million species. But taxonomists estimate that there are 4 to 30 million more species. Much of these species are unnoticed.

Importance of the biodiversity

There are following importance of biodiversity:

1. Biodiversity involve the production of renewable resources. These resources include food, wood and fresh water. We get different products from a variety of plants like herbal medicines, plant juices, honey, wax etc.
2. Biodiversity lessen environmental change. It regulates climate of the region. It helps in pest/disease control.
3. Biodiversity provide cultural services for human value and enjoyment. These include landscape aesthetics, cultural heritage and outdoor recreation.
4. Forests hold back flood waters and recycle CO_2 and nutrients.
5. Insects pollinate crops and control insect pests.
6. The subterranean organisms promote soil fertility through decomposition.
7. Many of these undescribed species will provide new food crops, petroleum substitutes, new fibers and pharmaceuticals. All of these functions require large healthy populations.
8. Large populations promote the **genetic diversity**. This diversity is required for the survival of the species in the changing environmental. The genetic diversity is lost forever. The zoologists are trying to save endangered species. But they are able to save only a tiny portion of genetic pool.
9. Greater species diversity of plants may decrease herbivorous pest populations. Data from two separate studies suggest that greater diversity decreases pest populations.

Biodiversity and agriculture

Agricultural diversity can be divided into two categories:

a) **Intraspecific Diversity:** It includes the genetic variety within a single species, like the potato (*Solanum tuberosum*). It is composed of many different forms and types but all belongs to the same species, *S. tuberosum*).

b) **Interspecific Diversity:** It includes number and types of different species. Many small vegetable farmers grow many different crops like potatoes, and also carrots, peppers, lettuce etc.

Agricultural diversity can also be divided into planned diversity or associated diversity. This is a functional classification.

a) Planned diversity includes the crops which a farmer has encouraged, planted or raised (e.g. crops, covers, symbionts etc).

b) Associated diversity arrives among the crops. These are uninvited (e.g.: herbivores, weed species and pathogens, among others).

The control of associated biodiversity is one of the great agricultural challenges. Farmers try to eradicate associated diversity on monoculture farms,. They use biologically destructive pesticides. They use mechanized tools and transgenic engineering techniques. They also use crop rotation. Some polyculture farmers use the same techniques. They also use integrated pest management strategies.

Benefits of biodiversity in agriculture

Interspecific crop diversity gives variety of crops. These crops give us food, clothing and wood. Intraspecific diversity, also give us choice in our diets. Sometimes, a crop fails in a monoculture. We rely on agricultural diversity. We replant the land with new resistant variety. Suppose a wheat crop is destroyed by a pest. Now we may plant a hardier variety of wheat next year. It us uses of intraspecific diversity. We may also stop wheat production in that area. Now we plant a crop of different species in this area. Now we rely on interspecific diversity. For example, The Irish potato blight of 1846 was a major factor in the deaths of one million people and migration of about two million. It was the result of planting only two potato varieties. Both were affected by blight, *Phytophthora infestans*. Use of biodiversity practices can control this problem.

Causes of destruction of biodiversity

The biodiversity is threatened all over the world. There are following reasons of destruction of biodiversity:

1. Acid rain, pollution, urban development, and agriculture are present everywhere. They are destroying the habitat of the organisms. Thus biodiversity is reducing in these areas.
2. The expanding human populations destroy the habitat. It is the main threats to biological diversity. Humans are exploiting about 40% net primary production on the earth. They convert the natural areas into agricultural land. They destroy the native species. The loss of habitat destroys thousands of native plants and animals.
3. Desertification and deforestation have also destroyed biodiversity.

4. Practice of monoculturing (planting single crop) in agriculture is also destroying the biodiversity. Only few selected species are grown. It lacks verities necessary for our survival.
5. Introduction of exotic species (non-local species) of plant are adversely affecting the endemic species (local species). Exotic species have many adaptive adaptations. Local species cannot compete with them. In this way, local species becoming extinct.

Conservation of biodiversity

Following steps can conserve biodiversity:

1. Process of deforestation should be checked strictly. Forest area in the country should be increased. Protection should be given to forest.
2. The process of aforestation and reforestation should be started. New forest should be established at new arid zones.
3. Steps should be taken to check desertification. Grazing should be checked. Overharvesting of trees should be banned.
4. Hunting should be banned or controlled.
5. National parks should be established. These parks should be well protected from the interference of local population.
6. Artificial breading should be carried out for endangered species.
7. Laws should be enacted to conserve natural resources.
8. Breeding sanctuaries should be established.
9. Botanical garden should be established at different sites to conserve local plant species.
10. Genetic banks of biodiversity should be established.
11. Practices of monoculturing of crop should be discouraged. Polycultural practices should be used.
12. Exotic species should be introduced in a region with proper study and research. Its impact on the local population should be thoroughly studied. Then this specie should be introduced.

CONSERVATION

The management of the earth resources to restore and maintain balance between human requirement and other species in the world is called conservation. Conservation includes continuous renewing of renewable resources. It is also applied to conserve non-renewable sources.

1 Air

Air is several kilometers thick blanket of atmosphere surrounding the earth. **Air is very important natural resource. It consists of these gases: Nitrogen (79%), Oxygen (20%), Carbon dioxide (0.03%), Traces of inert gases called noble gases.**

Oxygen is consumed during respiration. CO_2 and nitrogen are used as raw materials in a natural cycle for making food and other substances. These substances are required in living system. Air is being polluted rapidly due to industrialization and automobiles.

Polluted air contains certain gases like carbon monoxide, hydrocarbons and oxides of nitrogen and sulphur. Following steps can be taken to conserve air:

1. Air pollution should be checked.
2. Plants should be planted to increase the production of oxygen. They also absorb pollutants.
3. Production of excessive CO_2 should be reduced to check green house effect.
4. Environmental friendly fuel should be used.

2. Water

75% of the earth surface is covered with water. It is also a component of soil and air. It is also a major constituent of living organisms. It is 70 to 90% of the body weight. About 97% of the total water of planet earth is in oceans. 2% water is in the form of frozen ice — caps and only 1% as available fresh water in lakes, streams and rivers.

Main use of water are: Domestic / irrigation use 10%, Industrial utilization 90%, Water is used as raw material in making variety of foodstuff, drinks, liquid detergents and many other products. Sodium chloride is obtained from seawater, (table salt). This sodium chloride is used in cooking and manufacturing of other useful chemicals such as chlorine and sodium hydroxide. Following measures can be taken to conserve water resources:

1. Industrial chemical wastes are extremely toxic. They inhibit the natural purification of water. This purification is carried out by microorganisms. Chemical wastes degrade the river water and make it harmful for aquatic life. If pollution of fresh water resources continues, there will be shortage of fresh water supply in future. Therefore, measures should be taken to improve water sources.
2. Watershed management should be used to provide clean water for irrigation.
3. Recycling plants of water should be installed in the cities.

3. Soil conservation

Soil is destroyed due to poor land management. Man modifies it according to his own requirements. There is intensive cutting of trees and overgrazing. It causes soil erosion. Therefore, productivity of land is decreased. A low rainfall can give moderate productivity. But the land must have sufficient vegetation cover to hold rain water. Man is destroying such vegetation. It causes desertification.

Soil conservation involves retention of water. This water is used for growing and supporting vegetation. Its aim is to maintain or increase soil fertility and productivity. Vegetation covers check the erosion effectively. Contour ploughing and strip cropping are also important for checking erosion.

Greater understanding of crop, soil and climate is also a very important for better management of the soil. Soil management also include better dropping system, crop rotation, handling of crop residues, drainage of waterlogged and swampy soils, cleaning of toxic salts from the irrigated lands and irrigation of lands.

4. Conservation of biodiversity

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million species. But taxonomists estimate that there are 4 to 30 million more species. Much of these species are unnoticed. Following steps can conserve biodiversity:

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5. Conservation of Energy

We have faced energy shortage in the last decade. This shortage is caused due to rapidly decreasing supplies of fossil fuels. The fossil fuel is present in the form of coal, oil and natural gas. The energy resources can also be classified as inexhaustible and exhaustible.

(a) **Inexhaustible energy resource:** These resources includes solar energy, falling water (hydropower), wind, ocean thermal gradients, waves, tides, currents, geothermal and biomass.

(b) **Exhaustible energy resources:** These resources are fossil fuels like coal, oil and natural gas.

Exhaustible energy resources are present in fixed quantity in earth. So they have limited quantities and they will be exhaust sooner or later. It will affect the standard and life style of the future citizens. Thus these sources should be used properly and other sources of energy should be searched.

The energy sources on earth are limited. Hence, there should be balanced and planned use of energy resources. We can save energy by following ways:

1. Develop and use energy efficient machines, engines and manufacturing processes.
2. Reduce wastage by recycling.
3. There should be least use of vehicle. Go by walk or by public transport.
4. Switch off lights and electrical appliances when they are not in use.
5. Minimize the use of air conditioner.

6. Conservation of Forests

The forests have great economic and ecological importance. But deforestation has destroyed these natural resources. Following steps can be taken to conserve forests:

1. Process of Aforestation and reforestation should be started.
2. Over harvesting of the forest should be banned
3. Grazing should be checked in the forest.
4. Nurseries should be established.

WATERLOGGING

The soil which is saturated with water is called water logged soil. The saturation of soil with water is called waterlogging. Water table of the groundwater becomes much high in waterlogged soil. Thus the soil becomes saturated with water.

Causes of water Logging

Pakistan has one of the best canal systems in Pakistan. It is composed of 40790 canal miles. But some defects were found. It has created the twin problems of water logging. Some of the causes are:

1. **Construction of dams and barrages:** There are some of the largest dams and barrage in Pakistan like Terbela Dam and Sukkur barrage. The bed of these dams is made up of mud. Their walls are not made up of concrete. Thus water can easily seep through its bed and walls. It causes waterlogging in nearby areas.
2. **Defective canal system:** The canals in Pakistan are not lined during construction. Similarly, hardpan of canal beds is broken during digging of canals. Therefore, seepage of water takes place. It is estimated that 45-50% of the water is lost from different canals and land. It raises the water table of soil. Thus it causes waterlogging over large areas.
3. **Unscientific irrigation:** Our farmers have adopted unscientific irrigation system. Most of the water is collected in the ditches in the field. It causes water logging.
4. **Lack of drainage system:** Monsoon rain and frequent floods form small lakes and ponds also cause water logging. There is a lack of drainage system. Thus this accumulated water cannot be drained out. This water gradually seeped downwards and reached the water table. Thus it raises it ground water surface.
5. **Lower slope angle:** Soil surface of plains of Pakistan is flat. Its slop angle is much lower. Thus flow of water in streams, canals and rivers is much slow. Therefore, water has a lot of time to seep into the soil. It increases the water table and causes water logging.
6. **Rainfall:** Pakistan comes within the heavy monsoon rainfall area. Therefore, a lot of rain fall occurs in northern and coastal areas of Pakistan. This rain fall causes heavy flooding in southern areas of Pakistan. The land of Pakistan is porous. Therefore, water seep into the soil. It raises water table and cause waterlogging.
7. **Barrier to flow of water:** Roads and bridges in Pakistan are constructed without proper planning. These are constructed without proper drains for flood and rain water. Therefore, they become barrier to flow of flooded water. Thus water spread to nearly areas and seep into the soil. It causes waterlogging.

Affects of water logging

There are following affects of waterlogging and salinity:

1. **Effect on soil structure:** Water logging and salinity destroy the soil structure. Different layers of the soil are badly affected.
2. **Decreasing oxygen in soil:** The soil is saturated with water. Therefore, the oxygen content of the soil is decreased. Thus oxygen is not available to the roots of the plants for respiration. So the plants die.
3. **Promoting anaerobic conditions:** It causes anaerobic condition in the soil. Thus anaerobic microorganisms are produced in it. The anaerobic microorganisms produce methane (CH_4) and hydrogen sulphide (H_2S). These gases produce foul smell. They

make the soil unfit for other beneficial soil organisms.

4. **Deficiency of nitrogen in soil:** The number of aerobic organisms is reduced in waterlogged soil. It reduces the decomposition of the organic matter of the soil. It causes deficiency of nitrogen in the waterlogged soil.
5. **Leaching of soluble salts:** It causes deflocculation of soil. Water causes leaching of the soluble salts. Thus the upper soil layer is without nutrients.
6. **Effect in soil pH:** The soil pH become high and osmotic pressure is increased. It badly affects the plants and other soil organisms.
7. **Spreading of diseases:** Waterlogging is also injurious to public health. Mosquitoes and flies breed in waterlogged area. They spread malaria and other water borne diseases.
8. **Effects on buildings:** The farmers cannot construct their houses in waterlogged areas. The houses sink in the ground in these areas. Waterlogging also destroying the houses in villages, towns and cities. Cities of Peshawar and Faisalabad are badly affected by these problems.

Affects of water logging in Pakistan

Most of the plants cannot grow in waterlogged and saline conditions. Therefore, most of land of Pakistan has become barren. Water logging is destroying our irrigated lands rapidly. It can be compared with the cancer in the human body. We are unable to achieve self-sufficiency in food due to waterlogging. Most fertile and valuable lands of the country have wasted. The farmers are facing innumerable problems. It is badly affecting our economy. Waterlogging is affecting our lands at the rate of an acre a minute. According to a rough estimate it is affecting our lands at the rate of 1 lakh acre every year. There are total forty million acres of our irrigated areas. 5 million acres are severely affected by salinity. 12 million acres are suffering from salinity patches. 15 million acres are poorly drained or waterlogged.

Reclamation of soil from waterlogging

Following measures usually can be taken to check and reclaim the waterlogged soil.

1. **Lining of canals:** Canals should be lined with concrete. It will prevent the seepage of water. Process of lining of canal has been already launched in waterlogged areas of Pakistan. A large number of canals have been already lined.
2. **Installation of tube wells:** Installation of tube well is the most effective method of reclaiming the lands. The tube wells draw water from the land. They lower the water table. Tube wells are very beneficial in the localities where subsoil water is suitable for irrigation. It gives dual benefit. Firstly water level is lowered and secondly crops can be irrigated by the water. In some localities, tube well water is brackish. This water can be mixed with canal water for irrigation purposes.
3. **Drainage system:** Effective drainage system prevents the rise of the water table. These drains carry away saline water. Thus new drainage canals should be constructed and the older ones should be made efficient. Bed rocks should be broken for gravitational drainage.

4. **Scientific irrigation:** Irrigation should be done on scientific lines. Research should be carried out to determine the consumptive use of water by different crops. It can prevent loss of water through percolation to the deeper layers. The leveling of the fields should be done with laser land leveler. It makes the smooth flow of water thorough the agricultural fields.
5. **Use of manures:** Farm manure should be used at the rate of 10-20 tons per acre. This manure is composed garbage from the towns. It improves the soil structure porosity and nutrition. Gypsum is also beneficial for improving the soil structure.
6. **Plantation of trees:** Trees should be planted along both sides of the canals up to 500 feet. They make the wall of canal strong. It reduces the seepage of water from the canal bank. Secondly, this loss the seeped water by transpiration.
7. **Planting waterlogged resistant corps:** Rice, sugarcane, and barseen can be grown in waterlogged soils. These corps can be easily grown in waterlogged soil.

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Reclamation of soil in Pakistan

WAPDA has started different reclamation projects under the **SCARP** (Salinity Control and Reclamation Project). It is estimated that about 7 to 8 million acres of land has been reclaimed throughout Pakistan. In these localities water table has gone down and waterlogging has been eliminated. Crop acreage and crop yields have increased in these areas.

SALINITY

(کلراٹھا/ نمکین/ شوریدہ/ شور زدہ)

The soil in which salt crust is left due to evaporation of water is called saline soil and this problem is called salinity. The process of increasing the salt content is known as salinization. A saline soil has electrical conductivity of its saturation equal to or greater than **4m.mho per centimeter** and its exchangeable sodium percentage is **less than 15.** Its pH is less than 8.5. Saline soil has a large amount of salts. But saline soil does not contain enough exchangeable sodium ions. These salts interfere in the germination of plants. Saline soil has white incursion on the surface of soil. It is called **white alkali**. The soil is well flocculated. It contains chlorides and sulphate of sodium, potassium and magnesium. Salinity may be primary or secondary. **Primary salinity** is caused by natural causes like improper drainage. **Secondary salinity** is caused by rise of water table in the soil.

Best ph (6.8-7) ph

due to Human activities

(autogenic)/ automatic

Types of salt affected soils

There are three types of salt affect soil:

1. **Saline soil (thur):** The soil containing sufficient amounts of soluble salts affecting the germination and growth of most crop plants is called saline soils. Locally is called thur.
2. **Sodic soil:** The soil containing sufficient exchangeable sodium ions affecting plant growth is called sodic soils.
3. **Saline-sodic soil (bara thur):** The soil containing both soluble salts and exchangeable sodium in sufficient quantity are called saline-sodic soils. Locally it is called bara thur.

mixture of Na +other salts

Causes of Salinity

1. **Geological reasons:** The main reason which caused the salinity is geological ages. Most of the area now included in Pakistan was a vast sea in the past. It was called **Tethys Sea.** The sea changed its path. It left large quantity of salts. Then canal system was established in this area. The water table rises due to the seepage of water from canals. It brings out dissolved salts from the bed rocks. These salts caused salinity.
2. **Leaching of salts:** Most of the salts in irrigated and flooded water come from rocks. Weathering of rocks and minerals occur. Thus large quantities of salts are leached into water. Rain and flood water carry them into the ground water. The rising of water table in ground water bring these salts to the surface of soil. It causes salinity.
3. **Unlined canals:** Water seeps through the unlined canal banks and raises the water table. This water also contains dissolved salts of carbonate, sodium and potassium. Water is evaporated but salts are deposited on it. It causes salinity.
4. **Ground water:** Salinity can occur when the water table is between two to three metres from the surface of the soil. The salts from the groundwater are raised by capillary action to the surface of the soil. This occurs when groundwater is saline. A large area of Pakistan is affected by saline ground water. In some areas, tube wells are used to irrigate the land with such water. Salts are deposited on land. Thus land becomes saline.
5. **Irrigated water with salts:** The dissolved salts are also present in irrigated water. They also spread over the soil. Almost all water (other than natural rainfall) contains some dissolved salts. When the plants use the water, the salts are left behind in the soil. They accumulate in the soil. Since soil salinity makes it more difficult for plants to absorb soil moisture, these salts must be leached out of the plant root zone by applying additional water.
6. **Alluvial soil:** Large amount of salts are already present in the alluvial soils. These slats dissolve in the rising water table. It has increased the problem of salinity.

Effects of salinity

→ (more salt)

There are following affects of waterlogging and salinity:

1. **Effect on soil structure:** Salinity destroys the soil structure. Different layers of the soil are badly affected. Salts react with minerals present in the soil. Thus these minerals are in combine form. They are not now available to plants.
2. **Osmotic effect:** Most of the salts of saline soil are soluble in water. They increase the osmotic concentration of soil solution. Now roots cannot absorb water and minerals by simple diffusion. They have to undergo active transport for absorption of water and minerals. Thus a lot of energy is spent on it.
3. **Effect on growth of plants:** The growth of plants is very poor in saline soil. High salt contents adversely affect the plant. Salinity reduces the seed germination and growth in many plants. It reduces yield. Saline soil prevents uptake of Ca^{++} and Mg^{++} ions by plant. It causes deficiency of these ions in plants.

Reclamation of saline soil

1. **Flushing:** Saline soil contains chlorides and sulphate of sodium and potassium. These salts are soluble in water. These salts can be leached out with the help of water. This water can be passed into drains. This process is called **flushing**. Flushing of soil after planting rice crop is very helpful in controlling salinity.

کھیت کی
[illegible]

2. **Tillage practices:** Most of the salts in the saline soil make the soil hard. Therefore, different tillage practices are used to plough the field. They make soil soft and porous. It reduces the injury of plant roots by hard soil. It also provides oxygen to roots of the plants. Ridging of soil is done for seedbed preparation. It is good practice for growing plants in salt-affected soils. A high ridge is formed. It is sloped to the irrigation furrow. Salts are accumulated on this side. Seeds are then planted on the side of ridge.

بنانا / [illegible]

3. **Use of gypsum and other chemicals:** Chemicals like gypsum, sulphuric acid, sulphur and iron sulphate also help in control of salinity. Gypsum ($CaSO_4$) reacts with sodium (Na^+) to form sodium sulphate (Na_2SO_4). Sodium sulphate is leached out.

$$CaSO_4 + Na^+ \longrightarrow Na_2SO_4 + Ca^{++}$$

Sulphuric acid reacts with calcium carbonate to form calcium sulphate. It is leached out.

$$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + CO_2$$

4. **Use of tube wells:** The tube wells draw water from the land. They lower the water table. Thus salts are also flush down from the surface into the earth.

organic matter
دیسی کھاد

5. **Use of manure:** Farm manure should be used at the rate of 10-20 tons per acre. This manure is composed garbage from the towns. It improves the soil structure porosity and nutrition. Green manure also improves the mineral absorption ability of plants.
6. **Crops for moderate saline soils:** Soybean, spinach, cabbage, cauliflower, sweet potato, ginger, cucumber, pea sugar beet etc. can be grown in moderate saline soils.
7. **Salt resistant grasses:** Some grasses like ***Sporobolus arabicus, Cynodon dactylon, Chloris barbata*** and herbs like ***Melilotus albus, Trifolium fagelliferum*** are grown in saline soils. ***Sesbania bispinosa and Sesbania sesban*** **(Jantar)** is also beneficial in improving the soil. It adds nitrogen in it. Moreover, the deep roots of Sesbania bispinosa can also break the hard soil. The respiration of roots of Sesbania produces CO_2. It reacts with calcium carbonate and produce calcium bicarbonate $(CaHCO_3)_2$. It can exchange its calcium ion with sodium ions.
8. **Salt accumulating plants:** Some botanists have put forward the biotic treatment of salinity. It includes growing salt accumulating plants. These plants are ***Suaeda fruticosa, Suseda monoica etc***. These plants accumulate salts in crystalline and solution from in the cells of fleshy leaves. Thus it improves the soil.

POLLUTION

Pollution has been defined by Odum (1971) as **the undesirable change in the physical, chemical or biological characteristics of air, land and water that may affect the human life.** The pollutants cause undesirable physical and biological changes.

Man is searching for food and better living conditions. It has destroyed the environment.

Man has added a lot of dust, smoke, poisonous gases and radiations in the atmosphere. He has created problem of soil erosion, waterlogging and salinity. He has added injurious chemicals to the soil, river and sea due to the pesticide and fertilizers. He is throwing poisonous liquid, solid and gaseous waste in the surroundings. He has developed weapons and produced dangerous chemicals to kill other humans. Thus he is increasing pollution in the environment.

POLLUTANTS

Odum defines pollutant as **residues of things we make, use and throw away are called pollutants.** The pollutants may be:

1. The pollutant may be gases like CO, SO_2 etc.
2. These may be metals like lead, zinc, chromium etc.
3. There may be industrial pollutants like cyanide compounds, acetic acid acids.
4. Agriculture pollutants are pesticides, herbicides, fungicides and fertilizers.
5. Photochemical pollutants are ozone oxides, CFC (Chloroflouro carbon).
6. Radiations from radioactive substance also act as pollutants

There are two types of pollutants:

1. **Nondegradable pollutants:** The pollutants which are not degraded or degraded at very slow rate are called Nondegradable pollutants. These are mostly inorganic compounds like metallic oxides, DDT etc.
2. **Biodegradable pollutants:** The pollutants which are degraded by microorganism are called biodegradable pollutants. These include domestic sewage.

There are different types of pollutions, air, water, soil etc.

AIR POLLUTION

WHO (World Health Organization) defines air pollution in following words. **The presence of substances in the atmosphere produced directly or indirectly by man which affect his health and properties is called air pollution.**

Burning of the fuel, fossil fuel and waste of different kinds release poisonous gases. These gases are sulphur dioxide, carbon monoxide, hydrogen sulphide, fluorine, chlorine, ammonia, bromine, iodine, nitrogen oxide, ozone etc. Ethylene, acetylene, benzopyrene, propylene and many other hydrocarbons are also released as pollutant. Ethylene is released from automobiles, combustion of natural gas, coal or wood. Millions of tons of poisonous gases are released every year in industrial countries. These gases are produced by factories, electricity power, stations and automobiles.

Types of air pollutants

There are two types of air pollutants:

(a) Primary air pollutants

The substances which are emitted directly from some sources are called primary air pollutants. These include:

1. Sulphur compounds like SO_2, H_2S. These gases are produced by the oxidation of fuel.
2. Carbon compounds like CO, CO_2 and hydrocarbons. These compounds are produced by incomplete combustion of gasoline.

3. Nitrogen compounds are NO, NO_2 and NH_3.
4. Halogen compounds are HF, HCl. These are produced by the industrial processes.
5. Particles of different sizes suspended in air also act pollutant

(b) Secondary pollutants

The pollutants which are produced by the reactions of primary pollutants in the atmosphere are called secondary pollutants. These reactions may be:

1. **Photochemical reactions:** These reactions occur between nitrogen oxide, oxygen and waste carbons in the presence of light. It forms **peroxyacetly nitrate (PAN)** and ozone O_3. Similarly, Chloroflouro carbon (CFC) reacts with ozone layer. It is also a photochemical reaction. The chlorine of CFC react with O_3 and release O_2 and atomic oxygen. It causes ozone depletion or ozone hole.
2. **Acid rain:** In this case, sulphur dioxide (SO_2) reacts with rain water to form sulphuric acid. Sulphuric acid fall on soil with rain. It is called acid rain.
3. **Smog: The fog with smoke and chemical fumes forming dark and thick covering called smog.** Smog is very common in all industrial countries.

Effects of air pollutants

1. **Effect on plants:** Air pollutants have very dangerous effects on plants. Thick smog kills million of trees each year. An air pollutant causes tissue collapse and necrosis. They causes deplasmolysis of the cells. Some pollutants cause **chlorosis** in the leaves. Thus pale green or yellow patches appear in the leaves. Some pollutants cause shunted growth in plants. Acid rain also destroys different parts of the plants.
2. **Effects on animals and humans:** There are certain direct effects of pollutants in animals. They affect on respiratory tract and lungs. They cause **pulmonary edema,** chronic bronchitis and lung cancer. SO_2, NO_2 and NH_3 gases causes irritation in eyes and nose. These are suffocating gases.

   Carbon mono oxide (CO) is the most dangerous gas. It is produced by incomplete combustion of fossil fuel. It reacts with haemoglobin and form a stable compound **caroxyhaemoglobin.** It decreases the carrying capacity of haemoglobin for oxygen.

   Industries release many metals in the air like lead and chromium. These metals are carcinogenic. Similarly, some radioactive substance enters into the atmosphere. They also cause cancer.
3. **Green house effect:** CO_2 is released by the burning of fuel in industries. It forms a layer in the atmosphere. This layer allows the solar radiations to pass. But it does not allow the thermal radiation of earth to pass out. Thus temperature of the earth is continuously rising. It is changing the climatic pattern of the earth. Glaciers are melting rapidly and more evaporation take place form ocean. It causes sever flooding.
4. **Ozone depletion:** The photochemical reaction of CFC with Ozone produce ozone hole. Ozone filters most of the ultraviolet radiations. Now these radiations fall on the earth directly. These radiations have very lethal effects on human. They can cause skin cancer and other skin and eye diseases.

Control of air pollution

Following measures can reduce air pollution

1. High quality lead free petrol should be used. It has low sulphur contents.
2. Use of CNG (Compressed Natural Gas) also reduces the air pollution. It is environment friendly gas.
3. Two stroke engines should be replaced by four stroke engines. Four stroke engine do not produce CO.
4. All the industrialists should be bound to install treatment cells in the chimneys of their industries.
5. CFC gases should be replaced by green gas in refrigerators and air conditioners.

WATER POLLUTION

Life is impossible without water. Water is used in different activities like drinking, bathing, disposal of sewage, irrigation and for generating electricity. Undesirable pollutants are added in water. It causes pollution in water.

Sources and effects of water pollution

1. **Domestic sewage:** It includes household wastes. These wastes have food wastes, detergents and human feces. These wastes are drained into streams and rivers without treatment. Domestic sewage adds nitrogen and phosphate in water. Thus thick bloom of blue green algae is produced on water. It consumes oxygen at night. Therefore, most of the fishes die due to deficiency of oxygen. There is rapid decomposition of filament of algae. It produces unpleasant smell. **The increased productivity of lake caused due to enrichment of nutrients is called eutrophication.**
2. **Industrial effluents: Industrial waste is called effluents.** These are also discharged into the rivers. These wastes come from textile, sugar and fertilizer factories etc. Most of the industrial effluents are toxic. It kills the decomposing bacteria of pond, lake and river. Thus these water bodies become highly contaminated.

   The industrial effluents also contain some metals like iron, chromium, mercury, copper and cadmium. These metals cause harmful effects in humans. Mercury produces nervous disorder.
3. **Fertilizers:** Artificial fertilizers are used to improve the fertility of soil. Excess fertilizers seep into the ground water or it is carried into the drinking water. Fertilizers are very dangerous for human health. Nitrates of the fertilizers enter into the intestine of man. The intestinal bacteria change them into nitrites. The nitrites enter into the blood. They react with haemoglobin. Therefore, infants face the shortage of oxygen. This disease is called **methohemoglobinemia.**
4. **Pesticides and herbicides:** Pesticides are widely used to kill pests. These pesticides are carried away by running water into ponds and rivers. They finally reach the oceans. Some pesticides incorporate into the bodies of plants. The herbivores eat these plants. These pesticides go into their body. Finally herbivores are eaten by human. These pesticides go into human body. The amount of pesticides is increased at each trophic level. It is called **biological magnification.**

Pesticides and herbicides kill many phytoplanktons and zooplanktons. These also kill many fishes. DDT may cause cancer and nervous disorder in humans.

5. **Mineral oils:** Sometimes, oil is discharged into the oceans from oil ships. This oil is not dissolved in water. It is very dangerous for the ocean life.

Control of water pollution

1. Sewage should be treated properly before draining it into canals and rivers. Sewage treatment plants should be installed in all the cities.
2. Similarly, the effluents of the industries should be properly treated. Laws should be enacted to bind the industrialists to install treatment plants.
3. Fertilizers should be used in measured quantities.
4. Biological control should be preferred over pesticides.

LAND POLLUTION

Population is increasing day by day. Therefore, large area of land is becoming contaminated. There are different causes of contamination of land. There are following sources of land pollution:

1. **Industrial wastes:** The industries dispose off 165 million tone sold waste each year. The major sources of land pollution are cement, glass, fiber glass, paper industries. The solid wastes of these industries are deposited on the land. They make the land unfit for cultivation. The solid wastes of cement and textile industries cause lung diseases.
2. **Agricultural pollution:** The solid wastes of cement and paper industries deposits on soil. They damage the plants.
3. **Domestic pollution:** Domestic pollutant includes broken appliances, polythene bags, broken plastic, household garbage, animal wastes and glass wares. These pollutants destroy the natural beauty.

NOISE POLLUTION

Any unwanted sound is called noise. The dumping of unwanted sound into atmosphere is called noise pollution. Our county is facing the problem of urbanization and industrialization. Number of industries has been established in cites. These industries and vehicle produce a lot noise. Most the houses, schools and hospitals are located near noise polluted areas. Noise affects them badly.

Effects of noise pollution

Constant noise destroys man mentally and physically. It contracts the blood vessels. The skin becomes pale. Adrenaline is released as a result of noise pollution. It raises blood pressure. It also causes hypertension. High intensity sounds cause deafness. It causes headache, fatigue and nausea. It also affects the pregnant woman.

Control of noise pollution

1. Green belts should be established in open spaces in the cities. Plants are efficient absorber of noise. Thus they will absorb most of the noise.
2. Noise producing machinery should be installed in sound proof rooms.
3. No factories or building be constructed in the 10 mile radius of airport.

SOIL EROSION

The wearing away of the topsoil by wind, water, snow or gravity is called soil erosion. Soil erosion is a naturally occurring process. It affects all landforms. It can occur by natural, physical forces of water and wind. It can also be caused by forces associated with farming activities like tillage.

Erosion involves three distinct actions. These are soil detachment, movement and deposition. Topsoil is high in organic matter. Fertility and soil life depends on it. Soil erosion reduces cropland productivity. It also causes pollution to adjacent watercourses, wetlands and lakes.

Whole of the sub-humid semi arid and arid zones of Pakistan is suffering from soil erosion. Over 160 million acres of land is suffering from wind or water erosion. About 35,000 acres of cultivable land is destroyed by soil erosion every year. Most of this area includes Potohar plateau and Baluchistan plateau.

Causes of soil erosion

Climatic, topographic, biotic, edaphic, and geologic factors cause the soil erosion.

1. **Climatic factors:** Wind and rainfall are climatic factors. These factors are directly responsible for soil erosion.
2. **Topographic factors:** Length of slope is a topographic factor. Higher length of slop increases the speed of flow of water. Thus water generates a large amount of energy. This energy is used to wear away upper layer of soil causing soil erosion.
3. **Biotic factors:** Uncontrolled grazing of vegetation by animals and cutting of vegetation by man are biotic factors. Bare land is more vulnerable to soil erosion. Crops and plantation reduce soil erosion.
4. **Edaphic factors:** Edaphic factors include physical, chemical and moisture characteristics of the soil. These factors affect soil erosion. **Soil erodibility** is an estimate of the ability of soils to resist erosion. It is based on the physical characteristics of each soil. Texture mainly affects erodibility. Structure, organic matter and permeability also contribute to it. Greater resistance to erosion is present in the soil:
   - Having faster infiltration rates
   - Higher levels of organic matter
   - improved soil structure

   Generally, sand, sandy loam and loamy soils are less erodible than silt and clayey soils.
5. **Geological factors:** The earthquakes, landslides and land upheavals are geological factors. They are also responsible for soil erosion.

Effects of Soil Erosion

Soil erosion affects the agricultural industry and natural environment.

1. Soil erosion erodes topsoil from an area. This area loses its most nutrient-rich layer. Therefore soil quality and fertility is reduced.

2. Poor soil produces smaller crop yields. It may even wash away seeds and small plants. Thus artificial fertilizers and pesticides are need in such soil.
3. Organic matter is found within the top layer of soil. Soil erosion removes it. It can weaken the ability of soil to hold water. It can create drought like conditions for plants.
4. Soil erosion carries away soil from fields. It carries with it contaminants like fertilizers and pesticides. This runoff can cause water pollution. It contaminates drinking water and disrupts ecosystems of lakes and wetlands. This negatively impacts the fish and wildlife.
5. Sediments accumulate down slope of the erosion. They can obstruct the flow of water in streams and drainage canals. It causes flooding.
6. Soil erosion causes silting problem of dams, waterways and streams. Desilting operation is used to remove this silt from these bodies. A huge money is spent on it. Silting reduces the lives of dams.
7. Wind can damage young seedlings by blasting them with sand and other small particles. Wind may bury other seedlings too deep.
8. Soil erosion makes the tillage operation difficult.

(A) WIND EROSION

Hot winds blow at a speed of 50-60 miles per hour in the arid and semi-arid regions Pakistan. It continuously removes the top soil covering. It replaces it with undesirable sand or silt. It blocks the canals, roads and railway tracts. In Pakistan main areas suffering from wind erosions are Thal, Tharparkar, Cholistan, Baluchistan and arid tracts between Hyderabad and Karachi.

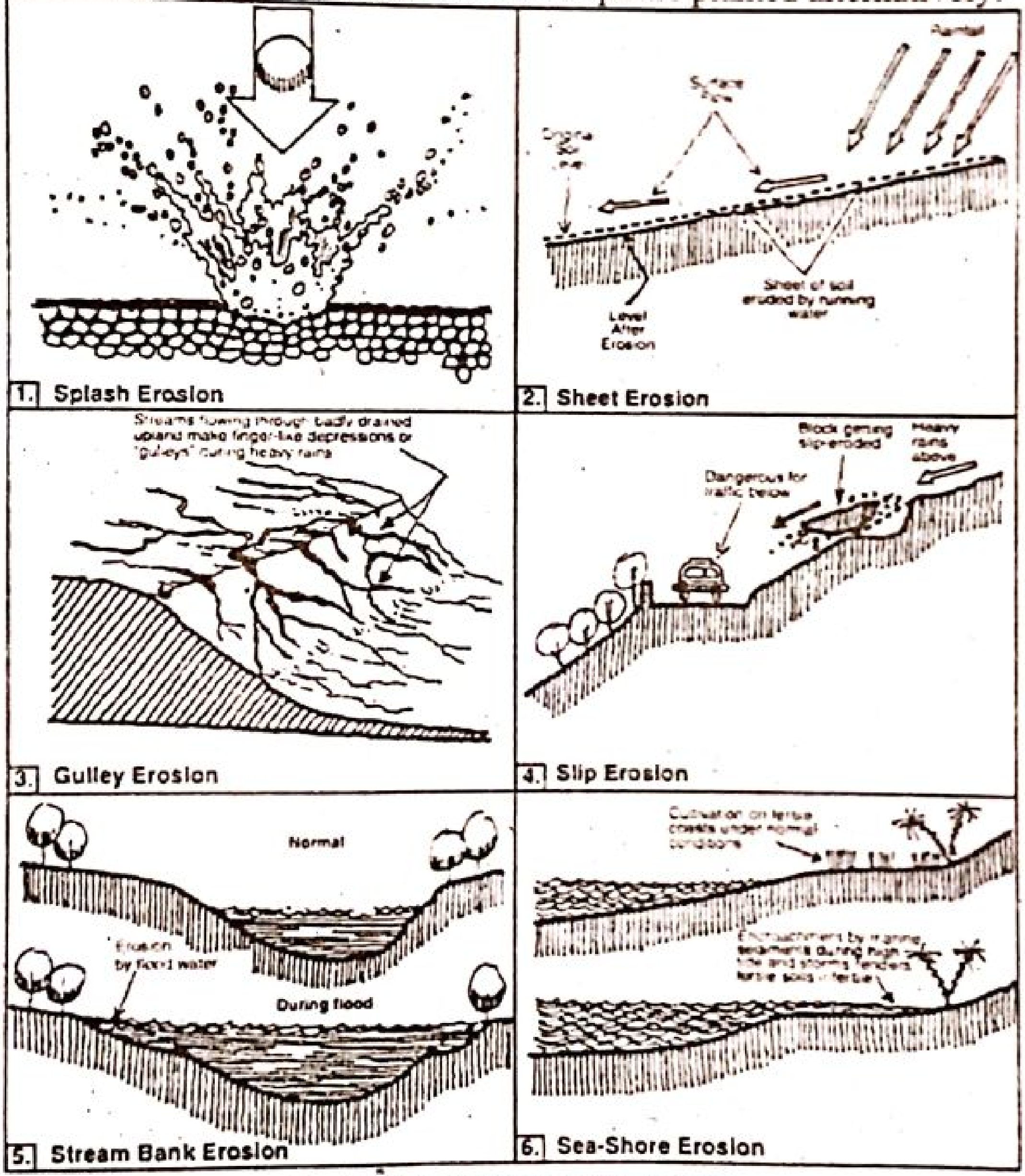
Soil Conservation Measures for Wind Erosion

Wind erosion can be prevented by following method:

1. **Shelterbelts:** Shelterbelts and wind breakers can check wind velocity. The species of *Tamarix dioica*, *Tecomella undultat*, *Prosopis cineraria* and *Euphorbia tirucalli* are grown as shelterbelts. These plants can resist the speed of high winds. Thus they break the pressure of wind.
2. **Aforestation:** The plantation of trees on new places is called aforestation. Aforestation can be carried out on banks of canals. It is a good method for checking soil erosion. Most of the land of Thal has been reclaimed by aforestation. Most common plants used in aforestation are *Dalbergia sisso* (Shisham), *Morus alba, Mellia azedarach, Prosopis cineraria, Prosopis Acacia nilotica* etc.
3. **Fences:** Soil erosion can also be checked by fences. The fences are usually 3 feet high and 120 feet apart. They are parallel to each other and at right angles to the wind.
4. **Fixation of Sand Dunes:** The species like, *Calatropis procera* (aak), *Prosopis cineraria, Tamarix Indica, Citrulus colocynthis* etc are good sand binders. They fix the sand dunes. Thus sand dunes are not dislocated by heavy wind.
5. **Basin Irrigation:** In this case, flood water or extra canal water is diverted towards

the sandy tracts. The silt of the flood water settles on the sand dunes. It is mixed up with sandy soil and fixes the sand dunes. Trees are planted on this land. They further stabilize the dunes.

6. **Control of cutting and overgrazing:** Overgrazing and trampling destroy the vegetation. It exposes the land. This land can be eroded by wind or water. Thus overgrazing and cutting of trees should be checked strictly.
7. **Strip Cropping:** In this case, crops are planted in strips. The strips are straight at right angles to the wind direction. The field is divided into alternate strips. Soil erosion resisting crops and erosion affected crops are planted alternatively.


Rainfall
Surface flow
Original Soil Level
Level After Erosion
Sheet of soil eroded by running water
Streams flowing through badly drained uplands make finger-like depressions or "gulleys" during heavy rains
Block getting slip-eroded
Heavy rains above
Dangerous for traffic below
Normal
Erosion by flood water
During flood
Cultivation on fertile coasts under normal conditions
Encroachments by migrating sediments during high tide and storms renders fertile soils infertile

1. Splash Erosion
2. Sheet Erosion
3. Gulley Erosion
4. Slip Erosion
5. Stream Bank Erosion
6. Sea-Shore Erosion

Fig: Different types of erosions

(B) WATER EROSION

The erosion caused by the action of water is called water erosion. The rain drops and surface flow action of water causes erosion. Water erosion is common in the regions with rainfall more than 20 inch. Water erosion has different types:

1. **Splash Erosion:** Raindrop falls on the soil surface. It damages the soil structure. The soil splits here and there. It is called splash erosion. Large quantities of soil are eroded by splashing. Soil losses by splashes are 50 times greater than runoff losses.
2. **Sheet Erosion:** In this case, flowing of water remove soil from large areas in form of sheet. It occurs by raindrop splash and runoff water. It typically occurs evenly over a uniform slope. It goes unnoticed until most of the productive topsoil is lost. Eroded soil deposits at the bottom of the slope or in low areas.
3. **Rill Erosion:** Sometimes, sheet erosion occurs with full force. The runoff water moves rapidly over the soil surface. It cut finger shaped channels or streams in the soil. These channels are called rills. In many cases, rills are filled in each year during tillage operations.
4. **Gully Erosion:** Several rills converge to form wide and deep cuttings. These cuttings are called as gully. Gully erosion is an advanced stage of rill erosion. Here channels become much larger. They interfere in normal tillage operations. Surface water runoff may cause gully formation or enlarging of existing gullies. It occurs due to defect in drainage systems.
5. **Gravitational Erosion or Land Slide:** Rain or snow water percolates through the rock and soil. It exerts pressure on them. Thus the weight of the rock is increased. The rock slides under the force of gravity. This is called as **landslide**.
6. **Bank Erosion:** Natural streams and constructed drainage channels are formed. They act as outlets for surface water runoff. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways. Poor construction practices, inadequate maintenance can lead to bank erosion problems.

Effects of water erosion

1. **Loss of fertility:** Soil erosion removes organic matter and plant nutrients from the soil. Thus it decreases soil fertility and productivity.
2. **Flooding:** Water erosion causes siltation. The runoff water carries a large amount of silt. This silt settles down in the pore spaces. Thus it completely seals off the soil. It checks percolation of water. Thus soil erosion takes place. The eroded soil continues to settle in the river bed. Therefore, it becomes shallow. Thus the river rises during monsoon season and causes floods.

Soil Conservation Measures for Water Erosion

The basic principles of conservation of water erosion include:

(a) Protection of soil from impact of rain drops
(b) Prevention of flow of water currents from a narrow path
(c) Slowing down of water flow on the slopes
(d) Improving the soil structure.

Following are some of the conservation measures.

1. **Crop Rotation:** The land should not be left naked in any part of the year. It should

always be remained covered with crops. Leguminous plants should be grown after cotton. Some grasses are used as fodder. They can be grown as soil cover.

2. **Contouring:** Ploughing is done along the direction of the slope. The rain water runs rapidly towards the same direction. It can take a large amount of soil with it. The slope is broken up into smaller compartments to prevent it. These compartments are called **contours**. Each bund holds water within each contour for a longer time. Thus it checks soil erosion. Sometimes, trenches are dug in the contours. It is called **contour trenching**.

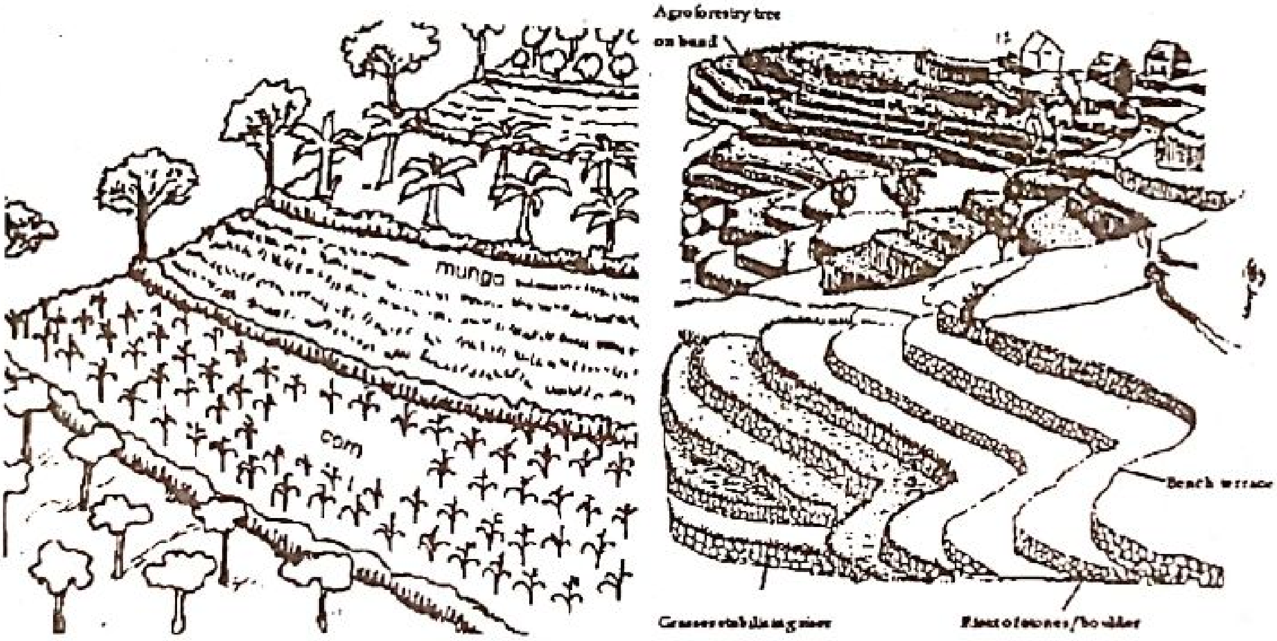


Fig: Contouring and terracing

3. **Contour Stripping:** In this case, crops are grown between strips on continued slopes. There are alternate strips of dense growing and soil covering crops. It checks the speed of flowing water and thus prevents soil erosion.
4. **Terracing:** In terracing, broad channels are constructed across a slope. A terrace is horizontal strip of length. It may be raised or in level. It is constructed on or near a contour. It decreases the length of the slope. Thus reducing the speed of flow of water. Therefore, it reduces soil erosion. It conserves rain water. Terraces of two types:
   a) **Broad Base Terraces:** It is a broad surface channel. It is constructed on lands up to 10% slopes. These are useful for reducing runoff erosion.
   b) **Bench Terrace:** Bench terraces are composed of series of steps. Each step has horizontal ridge. Vertical wall is present between two ridges. It converts a slope to a series of nearly level benches. Bench terracing is more common in hilly areas.
5. **Waterways:** Waterways are constructed in high rainfall areas. Some natural waterways also exist. Their banks can be made strong. Waterways can flow a large volume of runoff. They carry runoff from watershed without flooding. Waterways are

very helpful in reducing soil erosion in heavy rain areas.

6. **Dams:** Some localities have poor vegetation cover and they have high rate of soil erosion. Small dams should be constructed in these localities. They prevent siltation and floods. These dams can also store surplus water for irrigation purposes.
7. **Stream Bank Protection:** Stream bank erosion can be checked by lining them. *Saccharum munja* and *Saccharum spontaneous* should be planted along their banks. They also prevent erosion from stream banks.
8. **Mulching:** It is effective soil conservation method against wind and water erosion. In this method, the stalk of plants like maize, cotton, potato tops etc. are left in the soil. They are used as mulch. Mulching checks the rate of evaporation of moisture from the soils. It retards the erosion. It also increases the organic matter and improves the soil structure.

DESERTIFICATION

Spreading of deserts to the green areas is called desertification. Desertification occurs due to human activities. Desertification occurs in grasslands and forests. Earlier, vegetation was present there. But overexploitation of these natural resources changes them deserts. These are not natural deserts. But they are manmade deserts. Deserts are characterized by few vegetation and arid land. The ruins of Moenjodaro and Harappa are example of desertification.

Example of desertification

Desertification is occurring in the Sahel. Sahel is present at the borders the southern edge of the Sahara desert in Africa. There was below average rainfall for twenty-five years. There is also rapid growth of the human population in the Sahel. Thus desert is spreading towards southward.

Sahel is an example of an over population of human. This population is exceeding the carrying capacity of the land. So there is massive loss of the productivity from the ecosystem. This loss of productivity is irreversible. Therefore famines occurred in these area. The famine in Ethiopia in the mid 1980s gave tragic result.

Causes of desertification

There are following causes of desertification.

1. **Overgrazing and Trampling:** These are two main causes of desertification. Overgrazing destroy all the vegetations in the grasslands and forests. Trampling makes the soil unfit for vegetation. Therefore, few plants are left on land. Such lands are unable to support vegetation.
2. **Deforestation: The clearing of forests is called deforestation.** Deforestation is another cause of desertification. The humans are cutting trees for fuel wood and timbers. It destroys the forest. The process of regeneration is too slow. Thus the forest is changed into desert.
3. **Aridity:** The low moisture in the soil is called aridity. Aridity is another cause of desertification.
4. **Waterlogging and salinity:** Waterlogging and salinity is another causes of

desertification.

5. **Soil erosion:** Most of land of Pakistan is sandy. It has low content of silt and clay. Therefore, it can be easily eroded by water or wind. It makes the land unfit for cultivation.

Checking the process of Desertification

1. The unstable sandy surface of soil is stabilized temporarily or permanently. This can be done by spreading litter mulch or by spraying some binding chemicals.
2. Quick growing plants (shrubs, grasses) are planted at close spacing.
3. Hand watering or water sprinkling should be done during very early stages of vegetation establishment.
4. First phase of vegetation should be protected carefully.
5. Seedlings of other species are inter-planted. This vegetation will gradually replace first phase of vegetation.
6. Thinning and pruning must be delayed.
7. Peripheral farm lands of adjoining deserts should be provided with frequent tree shelter belts.
8. Crops or their stubbles be left standing in the field during hot dry summers.
9. Ploughing should be minimized.
10. Maximum quantities of a litter (organic mulch) should be added to fields.
11. Fertilizers should be added in many light doses. This will increase total production and will increase amount of litter/manure.

MANAGEMENT

There are following application of ecology in different environmental managements:

1. Land management

The operation by which land is prepared for crops plantation, harvesting is called land management. Good land management increases efficiency. Poor land management cause soil erosion, salinity and waterlogging. It changes the fauna and flora of the soil. Increased knowledge of ecology improves the land management techniques. These techniques are contour placing, terracing and strip cropping. It improves the crops and natural vegetation.

2. Soil management

Soil is destroyed due to poor land management. Man modifies it according to his own requirements. There is intensive cutting of trees and overgrazing. It causes soil erosion. Therefore, productivity of land is decreased. A low rainfall can give moderate productivity. But the land must have sufficient vegetation cover to hold rain water. Man is destroying such vegetation. It causes desertification.

Soil conservation involves retention of water. This water is used for growing and supporting vegetation. Its aim is to maintain or increase soil fertility and productivity. Vegetation covers check the erosion effectively. Contour ploughing and strip cropping are also important for checking erosion.

Greater understanding of crop, soil and climate is also a very important for better management of the soil. Soil management also include better dropping system, crop rotation, handling of crop residues, drainage of waterlogged and swampy soils, cleaning of toxic salts from the irrigated lands and irrigation of lands.

3. Forest Management

The ecosystem with predominant species of tall annual woody trees is called forest. The maintenance and sustaining of the forest is called forest management. The management of forests is the most important examples of applied ecology. Knowledge of successional trend and the climax of the region should be studied for studying forest ecology. The forest management includes:

1. Least disturbs the natural development of vegetation. The forest near climax stage is easier to maintain. Subordinate or dependent species should also be given importance in forest community. The subordinate plants act as indicator for evaluation of dominant species.
2. **Silvicultural** practices should be used to establish artificial forest in arid region. For this purpose, exotic species can be introduced in these areas.
3. Proper techniques of weeding cutting, planting, chemical and mechanical treatment should be used.
4. Protective measure should be taken against grazing, browsing, trampling by animals.
5. Positive selective thinning should be used to reduce competition among the trees.
6. Suitable pruning can improve the quality of wood.
7. Harvesting is done when mean annual increment (MAI) is highest.
8. There should be efficient logging, stacking, seasoning (drying), preservation and marketing.

4. Range Management

The grass land used by the animals for grazing is called rangeland. The application of science on rangeland for producing maximum number of grazing livestock regularly is called rangeland management.

Rangeland has great importance for livestock development. Unfortunately, man has changed most of the rangeland into agricultural land. Therefore, fewer rangelands left in the country. These rangelands are needed to be protected from overgrazing. Overgrazing can change a rangeland into desert. The optimum utilization of rangeland maintains the rangeland. It also provides continuous supply of milk and flesh to humans. There are following steps of rangeland management.

1. The palatability of grasses and forbs (associated herbs) should be tested. Most suitable livestock for these grasses should be introduced in this range land.
2. Effects of grazing on community structure should be given much attention. Carrying capacity of different kinds of grasslands should also be studied in different seasons of the year.
3. The water requirements of important grasses should be tested. The effects of different types of cover on runoff, flooding, erosion and water supply should also be studied.
4. **Exclosure technique** should be used to study rangeland. In this technique, a part of

rangelands is excluded from grazing. It is used to determine the nature of climax and related successional communities.

5. Introduction of foreign species should be discouraged. Seeding of native species should be done only with locally produced seeds.

5. Watershed Management

An area from which water fall in the form of rain or snow collects into a stream and river is called watershed. The storage of water for irrigation and for producing electricity by constructing dams and barrages is called water shed management. The aim of watershed is to control erosion and floods and to provide silt tree water.

There is a great importance of watershed management for Pakistan. According to the Indus water treaty 1960, Pakistan can use water from Indus, Jhelum and Chenab rivers only. Pakistan constructed two dams i.e. Tarbela and Mangla. Water storage capacity of these dams was 15 million acre feet. 4 barrages and 7 link canals were also constructed. But our dams are facing the problem of siltation. It is estimated that the Tarbela dam will fill with silt within 100 years. Its rate of siltation is highest in the world. Mangla dam will be filled with silt in 50 years. Silt extraction from the dams is uneconomical. Thus the sedimentation load can be reduced by watershed management techniques. It can prolong the life of our water reservoirs. There are following important steps of watershed management:

1. Trees and crops should be planted in the catchments. They reduce soil erosion and thus check the process of silting.
2. Terracing and contouring of the slopes of the rocks can also reduce erosion.
3. Socio-economic conditions of the people living in these areas should be improved. Awareness should be produced in them that they should not destroy natural vegetation. Grazing should be checked.

6. Wild life management

All non-cultivated plants and non-domesticated animals are included in wild life. Wild life plays very important role in food chain. The food chain is disturbed without wild life. So, it becomes very difficult to maintain the balance in ecosystem without wild life. Man is trying to change the environment. The effects of these changes in environment are becoming more and more apparent with the passage of time. The imbalance in wild life can jeopardize the existence of man. Following steps can be taken to save wild life:

1. Hunting should be banned.
2. National parks should be established.
3. Artificial breading should be carried out for endangered species.
4. Laws should be enacted to conserve natural resources.
5. Breeding sanctuaries should be established.

DEFINITIONS AND KEY POINTS FOR OBJECTIVES

TERMS	DEFINITIONS
Aridity	The word arid means dry. The dry land is called arid land. This problem is called aridity.
Arid climate	Arid climate is defined as the climate in which precipitation is less than the evapotranspiration in most part of the year.
Biodiversity	The variety of living organisms in an ecosystem is called biodiversity.
Conservation	The management of the earth resources to restore and maintain balance between human requirement and other species in the world is called conservation.
Water logging	The soil which is saturated with water is called water logged soil and this problem is called water logging.
Salinity	The soil in which salt crust is left due to evaporation of water is called saline soil and this problem is called salinity.
Pollution	Pollution has been defined by Odum (1971) as "the undesirable change in the physical, chemical or biological characteristics of air, land and water that may affect the human life.
Eutrophication	The increased productivity of lake caused due to enrichment of nutrients is called eutrophication.
Effluent	Industrial waste is called effluents.
Noise pollution	Any unwanted sound is called noise. The dumping of unwanted sound into atmosphere is called noise pollution.
Soil erosion	The wearing away of the soil by wind, water, snow or gravity is called soil erosion.
Desertification	Spreading of deserts to the green areas is called desertification.
Land management	The operation by which land is prepared for crops plantation, harvesting is called land management.
Forest management	The ecosystem with predominant species of tall annual woody trees is called forest. The maintenance and sustaining of the forest is called forest management.
Rangeland management	The grass land used by the animals for grazing is called rangeland. The application of science on rangeland for producing maximum number of grazing livestock regularly is called rangeland management.
Watershed	An area from which water fall in the form of rain or snow collects into a stream and river is called watershed.

Watershed management	The storage of water for irrigation and for producing electricity by constructing dams and barrages is called water shed management.

MODEL SUBJECTIVE QUESTIONS

1. **Write note on aridity.**
2. **Write not on biodiversity.**
3. **Write note on conservation**
4. **What is water logging? Give its causes, effects and control measures.**
5. **What is salinity? Give its causes and control measures.**
6. **Write note on water pollution.**
7. **Write note on air pollution.**
8. **Write note on noise pollution.**
9. **Write note on erosion and its types.**
10. **What is desertification? Give its effect and control measure.**
11. **Describe different types of managements.**

SHORT QUESTIONS

1. What is aridity and arid climate?

Ans: The word arid means dry. The dry land is called arid land. This problem is called aridity. Arid climate is defined as the climate in which precipitation is less than the evapotranspiration in most part of the year.

2. What are effects of Percolation and seepage rate on aridity?

Ans: It has great effect in aridity. High percolation and seepage rate promote aridity. Soil becomes dry. Sandy soil has high percolation and seepage rate.

3. Give effects of aridity.

Ans: Aridity has adverse affect on crop production. The productivity of arid land is far less. Most of the arid lands depend on rain for water. There is unequal distribution of rain throughout the year. Therefore, very few crops can be grown in these regions.

4. What is mulching?

Ans: Soil must be covered with shallow cultivation. The stumps of the plants should not be removed after harvesting. They act as natural mulch and increase the water holding capacity of soil. Straw mulch is also affective in reducing evaporation of water.

5. What is biodiversity? What are total numbers of species?

Ans: **The variety of living organisms in an ecosystem is called biodiversity.** The exact number of species in the world is not known. The taxonomists have described about 1.4 million species. But taxonomists estimate that there are 4 to 30 million more species.

6. Define conservation.

Ans: The management of the earth resources to restore and maintain balance between human requirement and other species in the world is called conservation.

7. Give two methods to conserve energy.

Ans: Develop and use energy efficient machines, engines and manufacturing processes. Reduce wastage by recycling. There should be least use of vehicle. Go by walk or by public transport.

8. What is water logging?

Ans: The soil which is saturated with water is called water logged soil and this problem is called water logging.

9. Give two effects of water logging.

Ans: Water logging and salinity destroy the soil structure. Different layers of the soil are badly affected. The soil is saturated with water. Therefore, the oxygen content of the soil is decreased. Thus oxygen is not available to the roots of the plants for respiration. So the plants die.

10. What is salinity?

Ans: The soil in which salt crust is left due to evaporation of water is called saline soil and this problem is called salinity.

11. What is flushing?

Ans: Saline soil contains chlorides and sulphate of sodium and potassium. These salts are soluble in water. These salts can be leached out with the help of water. This water can be passed into drains. This process is called **flushing.**

12. Name plants used to reclaim saline soil.

Ans: Some grasses like ***Sporobolus arabicus, Cynodon dactylon, Chloris barbata*** and herbs like ***Melilotus albus, Trifolium fagelliferum*** are grown in saline soils.

13. Define pollution.

Ans: Pollution has been defined by Odum (1971) as "the undesirable change in the physical, chemical or biological characteristics of air, land and water that may affect the human life.

14. What are Nondegradable pollutants?

Ans: The pollutants which are not degraded or degraded at very slow rate are called Nondegradable pollutants. These are mostly inorganic compounds like metallic oxides, DDT etc.

15. Define air pollution.

Ans: The presence of substances in the atmosphere produced directly or indirectly by man which affect his health and properties is called air pollution.

16. What are the effects of CO on body?

Ans: **Carbon mono oxide** (CO) is the most dangerous gas. It is produced by incomplete combustion of fossil fuel. It reacts with haemoglobin and form a stable compound **caroxyhaemoglobin.** It decreases the carrying capacity of haemoglobin for oxygen.

17. What is green house effect?

Ans: CO_2 is released by the burning of fuel in industries. It forms a layer in the atmosphere. This layer allows the solar radiations to pass. But it does not allow the thermal radiation of earth to pass out. Thus temperature of the earth is continuously rising. It is changing the climatic pattern of the earth.

18. What is biological magnification?

Ans: Some pesticides incorporate into the bodies of plants. The herbivores eat these plants. These pesticides go into their body. Finally herbivores are eaten by human. These pesticides go into human body. The amount of pesticides is increased at each trophic level. It is called **biological magnification.**

19. What is soil erosion? Name factors cause it.

Ans: **The wearing away of the soil by wind, water, snow or gravity is called soil erosion.** Climatic, topographic, biotic, edaphic, and geologic factors cause the soil erosion.

20. What are shelter belts? Give their functions.

Ans: Shelterbelts and wind breakers can check wind velocity. The species of *Tamarix dioica, Tecomella undultat*, *Prosopis cineraria* and *Euphorbia tirucalli* are grown as shelterbelts.

21. What is splash erosion?

Ans: Raindrop falls on the soil surface. It damages the soil structure. The soil splits here and there. It is called splash erosion.

22. What is crop rotation?

Ans: The land should not be left naked in any part of the year. It should always be remained covered with crops. Leguminous plants should be grown after cotton. Some grasses are used as fodder. They can be grown as soil cover.

23. What are watershed and watershed management?

Ans: An area from which water fall in the form of rain or snow collects into a stream and river is called watershed. The storage of water for irrigation and for producing electricity by constructing dams and barrages is called water shed management.

OBJECTIVES

Multiple Choice Questions (MCQs)

1. Average rain fall in Pakistan is less than
(a) 400mm (b) 250mm (c) 340mm (d) 450mm

2. The percentage of earth covered with water is:
(a) 50% (b) 25% (c) 75% (d) 23%

3. The percentage of water in the form of frozen form is:
(a) 23% (b) 2% (d) 10% (d) 56%

4. The taxonomists have described species:
(a) 1.5 million (b) 1.4 million (d) 1.6million (d) 1.7million

5. The length of canals in Pakistan is:
(a) 40790 miles (b) 80790 miles (c) 47790 miles (c) 10790 miles

6. Which of the followings is secondary pollutant?
(a) CO (b) S (c) PAN (d) HI

7. Photochemical reaction produces:
(a) CO (b) S (c) PAN (d) HI

8. Green house effect is caused by:
(a) CO (b) CO_2 (c) H_2 (d) CFC

9. Ozone depletion is caused by:
(a) CO (b) CO_2 (c) H_2 (d) CFC

10. Which of the followings is environment is green gas?
(a) LPG (b) CO_2 (c) H_2 (d) CNS

11. The length of slope is a:
(a) Topographic (b) Edaphic (c) Geological (d) Biotic

12. Physical, chemical and moisture characteristics of the soil:
(a) Topographic (b) Edaphic (c) Geological (d) Biotic

13. Number of acres suffering of soil erosion are:
(a) 100million (b) 120 million (d) 160 million (d) 200 million

Ans: 1. (b) 2. (c) 3. (b) 4. (b) 5. (a) 6. (c) 7. (c) 8. (b) 9. (d) 10. (d) 11. (a) 12. (b) 13. (b)

Fill in blanks

1. Air ____ is several kilometers thick blanket of atmosphere surrounding the earth.
2. The soil which is saturated with water is called water logged soil and this problem is called water ________.
3. The soil in which salt crust is left due to evaporation of water is called saline soil and this problem is called ______.
4. The presence of substances in the atmosphere produced directly or indirectly by man which affect his health and properties is called ______ pollution.
5. The fog with smoke and chemical fumes forming dark and thick covering called ________.
6. Two stroke engines should be replaced by four stroke engines. Four stroke engine do not produce _______.
7. The increased productivity of lake caused due to enrichment of __________ is called eutrophication.
8. The wearing away of the soil by wind, water, snow or gravity is called soil ________.
9. All non-cultivated plants and non-domesticated animals are included in _______ life.
10. _______ Diversity includes the genetic variety within a single species
11. ________ Diversity includes number and types of different species.
12. Air consists of these gases: _______ (79%), Oxygen (20%)
13. _______ of the earth surface is covered with water.
14. About _______ % of the total water of planet earth is in oceans.
15. The variety of living organisms in an ecosystem is called _______.
16. The soil which is saturated with water is called _______ soil.
17. The anaerobic microorganisms produce methane (CH_4) and _______.
18. Rice, sugarcane, and barseen can be grown in _______ soils.
19. WAPDA has started different reclamation projects under the _______
20. The soil in which salt crust is left due to evaporation of water is called saline soil and this problem is called _______.
21. The soil containing sufficient amounts of soluble salts affecting the germination and growth of most crop plants is called _______ soils.
22. Soil containing sufficient exchangeable sodium ions affecting plant growth is _______ soils.
23. The wearing away of the topsoil by wind, water, snow or gravity is called soil _______.
24. _______ factors include physical, chemical and moisture characteristics of the soil.
25. Soil _______ is an estimate of the ability of soils to resist erosion.
26. The plantation of trees on new places is called _______.
27. In strip cropping this case, crops are planted in _______.
28. The erosion caused by the action of water is called _______ erosion.
29. The slope is broken up into smaller compartments called _______ to prevent waterlogging.
30. Sometimes, trenches are dug in the contours. It is called contour _______.

Ans: 1. Air, 2. Logging, 3. Salinity, 4. Air, 5. Smog, 6. CO, 7. Nutrients, 8. Erosion, 9. Wild 10. Intraspecific, 11. Interspecific, 12. Nitrogen, 13. 75%, 14. 97, 15. Biodiversity, 16. water logged, 17. hydrogen sulphide, 18. Waterlogged, 19. SCARP, 20. Salinity, 21. Saline, 22. Sodic, 23. Erosion, 24. Edaphic, 25. Erodibility, 26. Aforestation, 27. Strips, 28. water , 29. Contours, 30. trenching

True/False

1. The dry land is called arid land.

2. The average rain fall is less than 250 mm in Pakistan.
3. Sandy soil has low water holding capacity.
4. Inorganic matter increases the water holding capacity of soil.
5. Straw mulch is also effective in reducing evaporation of water.
6. CAM Plant are particularly good for arid conditions.
7. The variety of living organisms in an ecosystem is called conservation.
8. The taxonomists have described about 1.4 million species.
9. Intraspecific Diversity includes the genetic variety within a single species
10. Intraspecific Diversity includes number and types of different species.
11. It consists of these gases: Nitrogen (79%), Oxygen (20%)
12. 75% of the earth surface is covered with water.
13. About 97% of the total water of planet earth is in oceans.
14. The soil which is saturated with water is called saline soil.
15. Trees should be planted along both sides of the canals up to 500 feet.
16. Rice, sugarcane, and barseen can be grown in waterlogged soils.
17. USA has started different reclamation projects under the SCARP
18. The soil in which salt crust is left due to evaporation of water is called saline soil and this problem is called salinity.
19. The soil containing sufficient amounts of soluble salts affecting the germination and growth of most crop plants is called saline soils.
20. The soil containing both soluble salts and exchangeable sodium in sufficient quantity are called sodic soils.
21. These salts can be leached out with the help of water. This water can be passed into drains. This process is called flushing.
22. The pollutants which are degraded by microorganism are called biodegradable pollutants.
23. The fog with smoke and chemical fumes forming dark and thick covering called fog.
24. Amount of pesticides is increased at each trophic level. It is called biological magnification.
25. The wearing away of the topsoil by wind, water, snow or gravity is called soil erosion.
26. Biotic factors include physical, chemical and moisture characteristics of the soil.
27. Soil erodibility is an estimate of the ability of soils to resist erosion.
28. The plantation of trees on new places is called aforestation.
29. In strip cropping this case, crops are planted in strips.
30. The erosion caused by the action of water is called wind erosion.
31. The slope is broken up into smaller compartments called contours to prevent waterlogging.
32. Sometimes, trenches are dug in the contours. It is called contour trenching.
33. Spreading of deserts to the green areas is called desertification.
34. The clearing of forests is called aforestation.
35. The ecosystem with predominant species of tall annual woody trees is called forest.

Ans: 1. T, 2, T, 3. T, 4. F. Organic, 5. T. 6. T, 7. F. biodiversity, 8. T, 9. T. 10. F. Interspecific, 11. T, 12. T, 13. T, 14. F. water logged, 15. T, 16. T, 17. F. WAPDA, 18. T, 19. T, 20. F. saline-sodic, 21. T, 22. T, 23. F. smog 24. T, 25. T, 26. F. Edaphic, 27. T, 28. T, 29. T, 30. F. water, 31. T, 32. T. 33. F. deforestation, 34. T, 35. T

(MODEL PAPER) B.Sc.
(FOR PUNJAB UNIVERSITY ONLY)
Botany Paper-D Physiology and Ecology
Part-II, Examination 2016 and onward

Time allowed: 30 Minutes Max. Marks: 14

Section – I Objective Type

Note: Attempt all questions of this section in the first 30 minutes and return the script to the examiner. Marks may be deducted for wrong spellings, erasing or overwriting.

Q. 1. Fill in the blanks (8 marks) Please fill in the blanks with appropriate terms/words

i. Temporary stage of decreased metabolism and growth rate is called ------------------.

ii. A condition during which layers of soil are permanently saturated is called ------------.

iii. ----------------------and -------------------- of soil surface by any physical agency is known as erosion.

iv. Breakdown of any --------------------------------- material is respiration.

v. ----------------------------- cells are functionally associated with the sieve elements of phloem in angiosperms.

vi. The enzymes are often referred to as biological -------------------------------.

vii. Growth / flowering response of plants to low temperature treatment is called ------ --------- ---------------------------.

viii. First stable product of photosynthesis in C_3 plants is --------------------------.

ix. The plant cells shrink due to------------------------------- in hypertonic environment.

x. Activities in plants are regulated by ----------------------------.

xi. ---------------------------- are ultimate parent material for soil.

xii. Total biomass in autotrophs is ---------------------- productivity.

xiii. Plant and animals constitute the ---------------------- component of ecosystem.

xiv. The part of species confined in certain area makes up its------------------.

xv. Murree hills are occupied by the plants predominantly belonging to ----------------.

xvi. Enzymes do affect reaction rate, what they do not affect is ---------------------------.

Q. 2. True or False statements (3 marks) Please select true or false statement by encircling 'T' or 'F' as appropriate

i. Growth movements involve gain or loss of water in pulvinus. T F

ii. Mg and Fe both are used to synthesize the phytal tail in chlorophyll. T F

iii. Loss of water from the surface of plant is transpiration. T F

iv. Wind as a factor, causes splash erosion. T F

v. Disintegration of rocks by plants is physical weathering. T F

vi. Alkaline sodic soils predominantly contain potassium, aluminum and sodium. T F

Q. 3. Multiple Choice Questions (3 marks) Please encircle the appropriate letter (a, b, c or d) of the correct answer.

i. The study of a single population and its interaction with the environment is called
e) Ecology b) Autecology c) Synecology d) lithology

ii. In a food chain, the amount of energy, from the base to the top always
a) increases b) decreases c) varies d) remains the same

iii. The species at the verge of extinction are
a) Endangered b) Threatened c) Extinct d) Extant

iv. The only living cells in xylem are
a) Parenchyma b) Vessels c) Tracheids d) Fibers

v. Inside the plant body water always moves via ---------------- pathway
a) Apoplast b) Symplast c) Vacuolar d) a, b, and c correct

vi. The pigment involved in photoperiodism is
a) Cytochromes b) Carotenoids c) Phytochromes d) Chlorophylls

(MODEL PAPER) B.Sc.
(FOR PUNJAB UNIVERSITY ONLY)
Botany Paper-D Physiology and Ecology
Part-II, Examination 2016

Time allowed: 2 hours 30 Minutes
Max. Marks: 21

Section – II Subjective Type

Note: Attempt any three questions. All questions carry equal marks. Draw neat and labelled diagrams along with captions where necessary. (3×7=21)

Q 1. a) Explain carbon fixation in C_3 plants (03)
b) Differentiate between 'Absorption' and 'Action' spectra (02)
c) Write a note on 'Reclamation of soil' (02)

Q 2. a) Explain the Quadrate method to study vegetation (04)
b) What is Vernalization? Explain its significance (03)

Q 3. a) What is soil parent matter? (02)
b) Write a note on biological nitrogen fixation (03)
c) What are the several roles of Auxins in plant metabolism (02)

Q 4. a) What is seed dormancy? Is it a useful phenomenon? Write in detail its causes and methods to break seed dormancy (04)
b) Explain your view point about food web (03)

Q 5. a) Define enzymes. How does an enzyme work? (03)
b) Differentiate between the terms 'Population' and 'community' (02) c) How does light affect vegetation (02)

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